Atlantic Richfield Company

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August 30, 2012

Mr. Steven Way
On-Scene Coordinator
Emergency Response Program (8EPR-SA)
U.S. EPA Region 8
1595 Wynkoop Street
Denver, CO 80202-1129

RE: St. Louis Tunnel Discharge Source Mine Water Treatability Study Work Plan

Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01

Dolores County, Colorado

Dear Mr. Way:

On behalf of Atlantic Richfield Company (Atlantic Richfield), please find enclosed the *St. Louis Tunnel Discharge Source Mine Water Treatability Study Work Plan* (Work Plan) prepared for the Rico-Argentine Mine Site (site). This Work Plan notifies the U.S. Environmental Protection Agency, Region 8, (U.S. EPA) of Atlantic Richfield's plans for conducting a treatability study to evaluate the potential to reduce metal loadings at the St. Louis Tunnel discharge by treating source water emanating from the Blaine-Argentine mine workings. Atlantic Richfield requests U.S. EPA's approval of this Work Plan pursuant to requirements in Task F – Water Treatment System Analysis and Design / Subtask F2 – Treatment System Conceptual Designs and Additional Investigations of the Remedial Action Work Plan accompanying the Unilateral Administrative Order for Removal Action, Rico-Argentine Site, Dolores County, U.S. EPA Region 8, dated March 9, 2011 (Docket No. 08-2011-0005).

If you have any questions regarding this Work Plan, please feel free to contact me at (714) 228-6770 or via e-mail at Anthony.Brown@bp.com.

Sincerely,

Tony Brown

Project Manager Mining Atlantic Richfield Company

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Enclosures: St. Louis Tunnel Discharge Source Mine Water Treatability Study Work Plan

Mr. Steven Way U.S. EPA Region 8 August 30, 2012 Page 2 of 2

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ST. LOUIS TUNNEL DISCHARGE SOURCE MINE WATER TREATABILITY STUDY WORK PLAN Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01 Rico, Colorado

Submitted to:
Atlantic Richfield
La Palma, California

Submitted by:

AMEC Environment & Infrastructure, Inc. Rancho Cordova, California

August 2012

Project No. SA11161301



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LIST OF ACRONYMS

AMEC AMEC Environment & Infrastructure, Inc.

Atlantic Richfield Atlantic Richfield Company

CDRMS Colorado Division of Reclamation, Mining and Safety

CERCLA Comprehensive Environmental Response, Compensation and Liability Act

DO dissolved oxygen g/L gram per liter gpm gallon per minute

HSSE Health, Safety, Security and Environment

K₂CO₃ potassium carbonate LiCl lithium chloride LiOH lithium hydroxide mg/L milligram per liter NaBr sodium bromide NaCl sodium chloride NW northwest

ORP oxidation reduction potential RAWP Removal Action Work Plan SAP Sampling and Analysis Plan

SE southeast

site Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01, Dolores

County, Colorado

SOP Standard Operating Procedure
TSEA Task Safety Environmental Analysis
UAO Unilateral Administrative Order

U.S. EPA U.S. Environmental Protection Agency

Work Plan St. Louis Tunnel Discharge Source Mine Water Treatability Study

Work Plan



ST. LOUIS TUNNEL DISCHARGE SOURCE MINE WATER TREATABILITY STUDY WORK PLAN

Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01 Dolores County, Colorado

1.0 INTRODUCTION

This *St. Louis Tunnel Discharge Source Mine Water Treatability Study Work Plan* (Work Plan) has been prepared by AMEC Environment & Infrastructure, Inc. (AMEC) on behalf of Atlantic Richfield Company (Atlantic Richfield) to describe the scope of work to be conducted to evaluate the treatability of water within the underground workings at the Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01 (site). The site is located in the San Juan Mountains of southwestern Colorado, just north of the Town of Rico in Dolores County, Colorado (Figure 1). The site consists of the St. Louis Tunnel and associated complex of underground mine workings as well as a series of settling ponds. A general site layout is presented in Figure 2.

The activities described in this Work Plan are being conducted pursuant to the *Unilateral Administrative Order for Removal Action (UAO), Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Docket No. 08-20011-0005*, effective March 23, 2011 (UAO; U.S. Environmental Protection Agency [EPA], 2011), and the Removal Action Work Plan (RAWP) dated March 9, 2011, in connection with the site.

This Work Plan outlines the steps to test the feasibility of in-situ treatment of water within the underground workings and evaluate the resulting effect on metals loading in the St. Louis Tunnel discharge.

1.1 HEALTH, SAFETY, SECURITY, AND ENVIRONMENT EXPECTATIONS

All tasks described herein will be performed in accordance with the Task Specific Health, Safety, Security, and Environment (HSSE) Plans prepared by Atlantic Richfield's contractors. The appropriate Risk Assessments, Task Safety Environmental Analysis (TSEAs), Standard Operating Procedures (SOPs), and permits will be completed prior to initiating any of the work described herein.

All underground work will be performed by the Colorado Division of Reclamation, Mining and Safety (CDRMS) in conjunction with the United States Environmental Protection Agency



(U.S. EPA). The CDRMS and U.S. EPA are responsible for managing the health and safety of their personnel and subcontractors. Coordination and Responsibilities

This St. Louis Tunnel discharge source mine water treatability study was designed to minimize the amount of underground work required for implementation. The bulk of the equipment necessary to implement the treatability study will be located at the surface near the outside of the Argentine mine portal. The treatability study activities will be distributed between the CDRMS in conjunction with the U.S. EPA and Atlantic Richfield providing equipment and contract personnel for out-of mine support. Detailed roles and responsibilities will be reviewed with the entire team prior to the start of work.

2.0 BACKGROUND

The St. Louis Tunnel portal drains historical mine workings that extend several thousand feet into Telescope Mountain to the north and Dolores Mountain to the southeast (SE) (Figure 3). The mine workings to the northeast of the site (Pigeon, Logan, Wellington, and Mountain Springs mines) are or were hydraulically connected to the St. Louis Tunnel via the Northwest (NW) Cross-cut. The workings in the southeastern portion of the site (Argentine, Blaine, Blackhawk, and other mines, collectively referred to herein as the Blaine-Argentine mine workings) are hydraulically connected to the St. Louis Tunnel via the SE Cross-cut (Figure 3). The Blaine and 517 Shaft Access Tunnels provide access to the underground mine workings approximately 500 vertical feet above the St. Louis Tunnel level. Various interconnected "vertical" mine workings (shafts, raises, winzes, inclines, drifts, adits) and mined-out stopes provide inferred opportunities for hydraulic connection of flows in and through the "horizontal" mine workings (i.e., the Blaine and 517 Shaft Tunnels at the 100 level and the underlying 200, 300, and 400 levels to the SE Cross-cut at the 500 level. These interconnected workings direct infiltrating precipitation (primarily snowmelt) as groundwater to the St. Louis Tunnel. As the groundwater travels through the workings, oxidation of mineralized rock increases the heavy metal concentrations in the mine water.

Preliminary assumptions regarding flows and pH measurements expected in late summer and early fall at the Blaine Tunnel, 517 Shaft, and St. Louis Tunnel adit were derived from the tracer studies and water sample collection and analysis, which were conducted in the fall of 2011 (URS, 2012) and the Blaine Base Flow Test conducted in July 2012 and include:

	Flow Rate (gallons per minute)	pH (standard units)
Blaine Tunnel	25 ^a	2.4
517 Shaft	75 ^a	3.2
St. Louis Tunnel Adit	750 ^b	6.8

Notes:

a flow rate inferred from tracer studies

^b flow rate directly measured



Evaluation of laboratory analytical data summarized in Table 1 and metals and sulfate loading data summarized in Table 2, derived from water samples collected from the Blaine Tunnel, 517 Shaft, and St. Louis Tunnel, suggests the following:

- Metals Loading at the St. Louis Tunnel portal:
 - o Roughly 50% originates from the SE Cross-cut (Blaine Tunnel and 517 Shaft).
 - Roughly 50% originates from the NW Cross-cut and mine workings north of the St. Louis Tunnel.
- Interaction and attenuation of flows between the Blaine Tunnel and the 517 Shaft:
 - The Blaine Tunnel appears to be the major source of metals loading to the 517 Shaft.
 - o Flows from the Blaine Tunnel are diluted approximately 3:1 at the 517 Shaft.
 - Approximately 90% of the dissolved iron loading from the Blaine Tunnel is attenuating before reaching the 517 Shaft.
 - Analytical results suggest that sufficient alkalinity is being added to the system naturally between the Blaine Tunnel level and the 517 Shaft at the 500-foot level to raise the pH of the water enough to precipitate iron hydroxide and that sufficient dissolved oxygen (DO) is available to oxidize iron.
 - Metals including copper, manganese, and cadmium are precipitating from solution between the Blaine Tunnel and the 517 Shaft; however, it appears that the pH is not high enough to result in the same reduction for these metals as is observed for dissolved iron.
 - Metal loadings of manganese, zinc, and cadmium increase between the 517 Shaft and the St. Louis Tunnel portal, suggesting substantial loading may be coming from mine workings north of the St. Louis Tunnel via the NW Cross-cut. This is supported by results from historic samples collected from the NW Cross-cut at its intersection with the St. Louis Tunnel.

This evaluation suggests that additional metals removal may be achieved by slight enhancement to the natural neutralization that is observed to be occurring within the underground workings and forms the basis for the proposed pilot test outlined in the following sections.

3.0 PURPOSE AND OBJECTIVES

The purpose of this work is to evaluate the potential to reduce metal loadings at the St. Louis Tunnel discharge by treating source water emanating from the Blaine-Argentine mine workings. Successful treatment of flows from the Blaine-Argentine Mine workings as



accessed in the Blaine Tunnel (likely via the Humboldt Drift and Morris Cook Incline) and the 517 Shaft may also provide additional data on the contribution of metal loads from the NW Cross-cut to the St. Louis Tunnel discharge. Incremental adjustments to the treatment injections at the 517 Shaft may also provide information as to the feasibility of in-situ treatment of waters from the NW Cross-cut via injections at the 517 Shaft. Source water treatment at the Blaine Tunnel and 517 Shaft may reduce metals loading at the St. Louis Tunnel discharge and could subsequently result in reducing the overall water treatment design capacity and solids handling and disposal requirements for reducing the metal loads to the Dolores River.

This Work Plan describes the proposed design and implementation of a treatability study and associated tracer tests to assess a possible method for mitigating metals loading at the St. Louis Tunnel discharge. The primary objective of the proposed work is to evaluate the impacts of alkaline injection at the 517 Shaft on metals loading in the discharge from the St. Louis Tunnel portal. The specific objectives of the proposed field tests are to:

- Determine changes in metals concentrations and other water quality parameters at the St. Louis Tunnel discharge in response to injection of an alkaline solution at the 517 Shaft;
- Determine the effects of different alkaline dosing rates at the 517 Shaft on metals concentrations in the St. Louis Tunnel discharge;
- Evaluate the residence time distribution of water flowing between the 517 Shaft and the St. Louis Tunnel discharge using a short-term injection of a conservative tracer; and
- Estimate the mine water flow rates (i.e., flow through the 517 Shaft into the St. Louis Tunnel and flow from the NW Cross-cut into the St. Louis Tunnel) using a continuous injection of conservative tracer.

Although the objectives of this work will be limited by seasonal and climatic (i.e., wet year versus dry year) variations in flow rates and metals loading that have been observed at the St. Louis Tunnel discharge, the treatability and tracer test results will support an initial assessment of the potential viability of this treatment approach. Treatability test results will be used to evaluate the need for further testing and will form a basis from which future treatability tests and larger scale treatment systems may be designed and evaluated.

4.0 PROJECT OVERVIEW

To meet the treatability study and tracer test objectives, AMEC has organized the proposed field work into the following three phases that will be implemented sequentially:



- 1. Pre-Injection Test Work The initial phase will include mobilization, equipment setup, and baseline sampling to determine initial geochemical conditions.
- 2. Injection After test equipment has been set up and baseline conditions have been established, injection of tracer solutions and alkaline solutions will commence at the 517 Shaft. Initially, a conservative tracer will be injected over a short time frame to estimate the residence time of mine water between the 517 Shaft and the St. Louis Tunnel discharge. This will be followed by continuous injection of an alkaline solution with a conservative tracer to evaluate changes in water chemistry at the St. Louis Tunnel discharge and hydraulic characteristics of the mine workings.
- 3. Post-injection After completion of injection tests, additional sampling and field monitoring will be conducted to monitor the return to baseline geochemical conditions. Demobilization tasks will also be completed during this phase.

Specific tasks that will be completed and additional details for each of these three phases are described further in the following section. In addition to the activities described below, additional characterization work will be conducted at the 517 Shaft to enhance the understanding of how mine water enters and exits the shaft, evaluate the geometry of the shaft, evaluate the stratification of water chemistry within the shaft, and provide additional water quality data. Descriptions of this additional pre-injection test characterization work will be provided to U.S. EPA under separate cover. To generate data of acceptable quality that will meet the objectives of this proposed work, a Sampling and Analysis Plan (SAP) has been prepared to address field methods and sample collection and analysis. The SAP is included as Appendix A of this Work Plan. The sampling and analysis program for all phases of work is outlined in Table A-1 of the SAP.

5.0 PROJECT PHASES

This section describes the major components and rational for each component of the three project phases.

5.1 PRE-INJECTION

The pre-injection phase of the proposed work will consist of mobilization, setup, and baseline sampling. This phase will take place prior to injection of the tracer and alkaline solutions.

5.1.1 Mobilization/Setup

All materials and supplies will be shipped to and received at the site, and all components of the injection system will be constructed, checked, and tested. System construction and installation will include external components (outside the 517 Shaft Access Tunnel, to be completed by Atlantic Richfield's contractors) and components that will be installed inside the 517 Shaft Access Tunnel (to be completed by CDRMS).



The system includes the following general components as presented in the generalized process flow diagram for the treatability study system (Figure 4).

- Chemical storage tanks for concentrated chemical solutions and diluted injection solutions;
- Chemical mixing equipment;
- Fluid transfer lines for chemical transfer and mixing;
- Injection pump;
- Injection line from injection pump to mine water in the 517 Shaft;
- Flow meter and flow totalizer on injection line;
- pH probe submerged in the 517 Shaft mine water; and
- Power supply.

In addition to system construction, chemical solutions will be delivered to the site and injection solutions will be prepared during the pre-injection phase. Tracers will be delivered as solid salts (e.g., sodium bromide [NaBr] and sodium chloride [NaCl]) that will be mixed into injection solutions on site. The alkaline solution will be 47 percent (%) potassium carbonate (K_2CO_3) delivered by a tank truck.

5.1.2 Baseline Sampling

Baseline water samples will be collected to establish initial, pre-injection conditions. Pre-injection samples will be obtained from the 517 Shaft and the St. Louis Tunnel discharge (at the existing sampling location "DR-3"). The sample from the 517 Shaft will be obtained by U.S. EPA/CDRMS personnel using a bailer. Water from Silver Creek will also be sampled to characterize the dilution water used to prepare injection solutions. Baseline samples will be collected and analyzed as described in the SAP (Appendix A).

Baseline water quality parameters will also be measured at the 517 Shaft and the St. Louis Tunnel discharge. Parameters to be measured will include pH, temperature, conductivity, oxidation reduction potential (ORP), and DO. To measure pH in the 517 Shaft, a data logging pH sensor will be calibrated and deployed into the shaft on a cable. Water quality parameters at the St. Louis Tunnel discharge (DR-3) will be measured similarly using a calibrated data logging field instrument.



After the system has been constructed and checked, and after the baseline samples and data have been collected, the injection phase will proceed.

5.2 INJECTION

Injection of tracers and alkaline solutions will commence after the pre-injection phase is complete. Specific injection tasks, including assumptions, are detailed below.

5.2.1 Short-Term Tracer Injection

Use of conservative tracers for assessing the hydraulic performance of groundwater and surface waters is well established in the literature (e.g., Kilpatrick and Cobb, 1985; Levenspiel, 1999; Metcalf and Eddy, 2003). Rapid tracer injections (i.e., pulse injections) are typically used to estimate the residence time distribution of fluid in a chemical "reactor". Measurement of effluent tracer concentration over time yields information about the mean residence time of fluid in the reactor, or in this case the underground workings. In the context of the proposed work, the primary goal of the short-term tracer injection will be to estimate the residence time distribution for fluid traveling between the 517 Shaft injection locations and the St. Louis Tunnel discharge location. The short-term tracer injection will also confirm that mine water is flowing through the 517 haft to the St. Louis Tunnel discharge. This information will be useful in estimating the minimum amount of time needed for observable geochemical changes to appear in the St. Louis Tunnel discharge. This information also has implications for the design of future pilot tests and more permanent mitigation methods within the mine workings.

NaBr will be used for the short-term tracer injection that will approximate a pulse tracer test. A batch of NaBr solution will be prepared by dissolving approximately 16 pounds of solid NaBr into 5 gallons of water from Silver Creek. A dissolved NaBr concentration of 400 grams per liter (g/L) will be targeted in the tracer solution, which is about half the NaBr solubility of 802 g/L in water. The solution will be injected at the 517 Shaft injection location at a flow rate of about 1 gallon per minute (gpm) using an injection pump and injection hose (Figure 4). At this injection flow rate, the entire 5-gallon volume of NaBr tracer solution will be injected to the 517 Shaft in about 5 minutes. Injection of alkaline solution will commence immediately after injection of the NaBr tracer solution.

Assuming complete mixing of the tracer into the mine water upon injection, the NaBr concentration at the 517 Shaft will be approximately 5,300 milligrams per liter ([mg/L], 1,200 mg/L sodium, and 4,100 mg/L bromide) for an assumed 517 Shaft mine water flow rate of 75 gpm and about 2,600 mg/L (600 mg/L sodium and 2,000 mg/L bromide) for an assumed 517 Shaft mine water flow rate of 150 gpm (the mine water flow rate through the 517 Shaft is one of the primary unknowns and cannot be directly measured). These concentrations are



well above the 517 Shaft background concentrations previously reported (URS, 2012). A sample from the 517 Shaft had bromide and sodium concentrations of about 0.03 and 7.4 mg/L, respectively. Samples from the St. Louis Tunnel discharge had bromide and sodium concentrations of about 0.02 and 9.5 mg/L, respectively. The low background bromide concentrations at the 517 Shaft and the St. Louis Tunnel discharge indicate that changes in bromide concentration will likely be easier to detect in the effluent as compared to sodium.

Once the injection of NaBr solution is complete, effluent concentrations of sodium and bromide will be monitored at the discharge of the St. Louis Tunnel. The primary assumptions of the short-term tracer test are that NaBr is a soluble, conservative material that will not affect flow of mine water and will not react or be retarded within the mine. After mixing into the mine water at the 517 Shaft, the tracer will travel identically to water and will be measurable in samples collected from the St. Louis Tunnel discharge.

The main data that will be obtained and evaluated are tracer concentrations at the St. Louis Tunnel discharge over time. The peak of a concentration versus time curve will indicate the mean residence time for fluid flowing between the 517 Shaft and the St. Louis Tunnel discharge. Additionally, mass balance calculations will be conducted to determine the fate of injected NaBr. The mass exiting the system will be estimated by numerical integration of concentration over time, and flow data, and this calculated mass will be compared to the known mass of injected NaBr. Tracer test data will be evaluated to determine the hydraulic characteristics of the mine using the methods described by Kilpatrick and Cobb (1985), Levenspiel (1999), and Metcalf and Eddy (2003). Short-term tracer test results will also be compared to results of the previous pulse tracer tests (URS, 2012), which found that peak concentrations of various tracers appeared at the St. Louis Tunnel discharge between 15 and 37 hours after rapid injection at the 517 Shaft.

5.2.2 Alkaline Injection

The goal of this phase of the study is to attenuate metals by altering water chemistry within the mine. Injection of a dilute alkaline solution directly into the mine water at the 517 Shaft is expected to increase the mine water alkalinity and pH at the 517 Shaft, thereby precipitating dissolved metals and reducing discharge of metals from the St. Louis Tunnel. Because of the many unknowns associated with the geochemistry and hydraulic characteristic of the mine workings, the injection test has been designed to be flexible and adaptable, based upon observed geochemical changes at the discharge of the St. Louis Tunnel. Analysis of samples taken from the St. Louis Tunnel discharge will be compared to baseline (pre-injection) samples to determine geochemical changes and treatment effectiveness. Samples will be sent to a fixed off-site laboratory for analysis of geochemical parameters (i.e., dissolved and total



metals, alkalinity, and anions). Alkalinity, dissolved zinc, and water quality parameters (pH, temperature, conductivity, etc.) will also be analyzed using field methods, for the purpose of rapidly generating data for decision making.

To increase the alkalinity and pH of the combined flows from the Blaine and 517 Shaft mine workings (and the Mountain Spring/ Wellington workings), K_2CO_3 solution will be injected into the 517 Shaft. Concentrated K_2CO_3 solution was selected for this test because it provides a soluble source of alkalinity, can be obtained in bulk as a concentrated solution, and is more soluble than soda ash (Na_2CO_3) at a given temperature.

A concentrated K₂CO₃ solution (47% K₂CO₃ by weight) will be trucked to the site and transferred to a storage tank by tank truck, each with a capacity of approximately 3,800 gallons. The concentrated K₂CO₃ will be diluted in batches by mixing at a 1:1 volumetric ratio in the Mixed Solution Tanks with water from Silver Creek. A tracer salt will also be mixed into each batch of alkaline injection solution to serve as a continuous tracer during injection (see Section 5.2.3). The resulting solution with 23.5% K₂CO₃ and tracer will be injected into the 517 Shaft. Preliminary chemical reagent demand and consumption calculations were made utilizing the analytical data collected in the fall of 2011 and are presented in Table 3.

A chemical metering pump with a flow rate range of 0.2 to 2.0 gpm will be used to continuously inject the K₂CO₃/tracer solution, after the initial batch NaBr tracer is injected into the 517 Shaft (the continuously-injected tracer test is described in Section 5.2.3). The injection hose will extend from the metering pump into the 517 Shaft Access Tunnel and down the 517 Shaft. A solid pipe section and injection nozzle will be connected to the bottom end of the injection hose, with the injection nozzle placed approximately 5 feet below the surface of the 517 Shaft mine water pool to disperse and promote mixing of the injected solution. If, however, during the pre-characterization evaluation, the inflow of water to the 517 is determined to be from above the water surface, then the injection nozzle may be placed at or above the water surface. The injection hose and nozzle will be affixed to and lowered by a stainless steel suspension cable using a mechanical reel to minimize elongation of the injection hose while suspended in the 517 Shaft. A pH probe will also be suspended in the mine water pool for real-time monitoring of pH changes while the alkaline solution is being injected.

Monitoring will be conducted to determine changes in water chemistry and to facilitate data evaluation. The total volume of injected solution will be measured using a totalizing flow meter installed on the injection line (Figure 4). Samples of each batch of injection solution will be sampled from the injection line and analyzed to verify the composition of injected solutions. At the 517 Shaft injection point, water samples will not be collected during injection due to inaccessibility and safety concerns. However, pH changes during the test will be monitored at



this location with a submerged pH probe connected to a data logging pH meter located outside the 517 tunnel portal. The pH probe will be deployed during setup of the test apparatus, and data will be recorded during the injection test.

The primary data set that will indicate treatment effectiveness will be changes in water chemistry at the St. Louis Tunnel discharge. Water samples from the existing monitoring location "DR-3" will be taken periodically and analyzed for total and dissolved metals concentrations; alkalinity; sulfate; and tracers. Sampling frequency and methodology, as well as analytical methods for parameters to be measured in a fixed laboratory and using field methods, are presented in Appendix A. Alkalinity, bromide, chloride, iron, and zinc will be analyzed using field methods during various parts of the test; samples will also be sent to a fixed laboratory for analysis of these and other parameters. Additionally, water quality field parameters (pH, temperature, conductivity, ORP, and DO) and the discharge flow rate will be monitored. The sampling, analysis, and monitoring program will be guided by the information provided in the task-specific SAP (Appendix A).

After a set period of injection (e.g., one week), or when effluent conditions have stabilized, the K_2CO_3 injection rate into the 517 Shaft may be altered to determine how dosage affects metals removal. Changes in K_2CO_3 dosage may include decreasing the dosage rate (by decreasing the injection flow rate and/or further diluting the K_2CO_3 solution) or increasing the dosage rate (by increasing the injection flow rate and/or increasing the concentration of the K_2CO_3 solution).

5.2.3 Continuous Tracer Injection

To assess the hydraulic characteristics of the mine workings between the 517 Shaft and the St. Louis Tunnel discharge, a conservative tracer will be continuously injected at the 517 Shaft with the alkaline solution. Results of the continuous tracer addition will be used to estimate flow rates through the SE Cross-cut into the St. Louis Tunnel, to determine if potassium in the injected alkaline solution can be used as a conservative tracer, and to assess the effect of different alkaline solution doses on removal of metals. This information has implications for the design of future pilot tests and the implementation of a more permanent mitigation method within the mine workings.

The continuously injected tracer will be a soluble salt that is mixed into the K_2CO_3 injection solution. In order of preference, the continuous tracer may be lithium hydroxide (LiOH), lithium chloride (LiCl), or sodium chloride (NaCl). The continuous tracer will be selected based on the factors discussed in the following paragraphs. The tracer will be continuously injected with the K_2CO_3 solution for the first week of the test to determine if potassium is conservative between the 517 Shaft and the St. Louis discharge. If potassium is conservative, it will be



used as the continuously injected tracer for the remainder of the injection test. If potassium is not conservative, continued addition of a separate tracer will be re-evaluated.

LiOH was injected to the 517 Shaft as part of the 2011 tracer tests conducted by EPA (URS, 2012). Lithium was found to be a sensitive, conservative tracer. Because the EPA tracer test was conducted in October 2011, detectable concentrations of residual lithium are unlikely to remain in subsurface mine water at the site. Lithium will be analyzed in baseline samples to determine any background concentrations, LiOH could be injected at a higher concentration than was used in the EPA tracer test, thus further improving the ability to detected injected lithium. The peak lithium concentration detected at the St. Louis Tunnel discharge was approximately 0.25 mg/L (URS, 2012). To achieve a steady state lithium concentration of 2.5 mg/L at the St. Louis Tunnel discharge (10 times the peak concentration observed in the EPA tracer test), approximately 550 pounds of LiOH would need to be added to each 3,800-gallon batch of K₂CO₃ solution, whereas a steady state lithium concentration of 1 mg/L would require dissolution of 220 pounds of LiCl¹.

LiCl could also be used as a continuously injected tracer. If LiCl is used as a tracer, both lithium and chloride would be present as tracers. However, the added chloride could potentially interfere with analysis of some anions and could potentially complex with some dissolved metals. To achieve a lithium concentration of about 10 times the peak concentration observed by EPA (i.e., 2.5 mg/L), approximately 1,200 pounds of LiCl would need to be added to each 3,800-gallon batch of K₂CO₃ solution, whereas a steady state lithium concentration of 1 mg/L would require dissolution of 485 pounds of LiCl¹.

NaCl is a relatively inexpensive and widely available salt that dissociates in water to Na and Cl ions, both of which can be used as tracers. However, the added chloride could potentially interfere with analysis of some anions and could potentially complex with some dissolved metals. If NaCl is used as the continuous tracer, a dissolved NaCl concentration of 12.6 g/L in the alkaline injection solution will be targeted (below the NaCl solubility of about 350 g/L), requiring dissolution of approximately 400 pounds of NaCl into each 3,800-gallon batch of alkaline injection solution. This will result in estimated sodium and chloride concentrations at the St. Louis Tunnel discharge that are about 1.2 and 10 times above background concentrations at DR-3, respectively.

AMEC Environment & Infrastructure, Inc.

¹ These calculations assume that the flow through the 517 Shaft is 75 gpm; the discharge from the St. Louis Tunnel is 750 gpm; the background lithium concentration is not detectable; and background chloride and sodium concentrations at the 517 Shaft and the St. Louis Tunnel discharge correspond to results presented by URS (2012).



Based on these calculations, LiOH is the preferred tracer. The selected tracer will be continuously injected with the alkaline solution at the 517 Shaft injection point, which has a target initial injection rate of about 0.3 gpm. Tracer ions (Na⁺, Cl⁻, or Li⁺, depending on the specific tracer salt used) will be monitored at the St. Louis Tunnel discharge to determine when steady state effluent concentrations have been achieved. The steady state effluent concentration of a conservative tracer will be used to estimate unknown quantities related to the mine workings, such as the mine water flow rate through the 517 Shaft into the St. Louis Tunnel and the mine water flow rate from the NW Cross-cut into the St. Louis Tunnel. The end point of the continuous tracer input will be after a steady state concentration of the tracer has been achieved in the St. Louis Tunnel effluent.

As with the short-term tracer injection, it is assumed that the continuously-injected tracer will completely mix into the mine water at the 517 Shaft. It is also assumed that the injected NaCl is a soluble, conservative material that will not affect flow of mine water and will not react or be retarded within the mine. After mixing into the mine water at the 517 Shaft, the tracer will travel identically to water and will be measurable in samples collected from the St. Louis Tunnel discharge. The goal of continuous injection of a conservative tracer is to achieve a steady state effluent tracer concentration at the St. Louis Tunnel discharge.

In addition to monitoring the tracer ions, potassium ion (K^+) concentrations will be monitored during alkaline solution injection as a potential secondary tracer. Potassium monitoring will be used to determine if K^+ is conserved as it flows with mine water between the 517 Shaft injection point and the St. Louis Tunnel discharge. If K is conservative, it can potentially be evaluated as a tracer in this and future injection tests. The expected K concentration at the St. Louis Tunnel discharge would be about 65 mg/L, assuming that the 23.5% K_2CO_3 solution is injected at 0.3 gpm and that the flow rate exiting the St. Louis Tunnel is 750 gpm (the estimated K concentration is relatively insensitive to flow rate through the 517 Shaft).

5.3 Post-Injection

After injections are complete, additional post-injection monitoring will be conducted prior to demobilization from the site.

5.3.1 Post-Injection Monitoring

Post-injection monitoring will be conducted for up to one week to evaluate the return to baseline conditions. The post-injection sampling and analysis program is outlined in Table A-1 of the SAP (Appendix A). At the St. Louis Tunnel discharge, water samples will continue to be collected and analyzed, and field monitoring of water quality parameters will continue for up to one week after injection is complete. One sample per day will be taken to characterize further



changes in metals concentrations discharging from the mine. At the 517 Shaft, one post-injection water sample per day will be obtained from the mine water pool in the 517 Shaft, near the injection point, for up to one week after injection is complete. All post-injection samples and field data will be collected in accordance with the SAP (Appendix A).

5.3.2 Demobilization

Upon completion of the injection test work at the 517 Shaft and sampling activities at the St. Louis Tunnel portal, all equipment will be properly decontaminated and disassembled in accordance with approved procedures. Equipment and materials will be demobilized from the Blaine and 517 Shaft Access Tunnels area and properly stored for possible future use at the site, and equipment rentals will be returned as required. The site location will be returned to match original conditions to the extent practicable.

6.0 IMPLEMENTATION SCHEDULE

All work described herein will be initiated and completed pending coordination and availability of Atlantic Richfield, U.S. EPA, and CDRMS contractors and subcontractors. Additionally, all work activities will have to be implemented in coordination with the Rehabilitation Project being implemented by CDRMS. Therefore, the estimated general schedule for the Source Mine Water Treatability Study is as follows:

- Phase 1, Pre-Injection: starting the week of September 4, 2012.
- Phase 2, Injection: estimated duration of 4 weeks, starting the week of September 17, 2012. Note that the injection duration could be modified (reduced or increased) based on observed results, and the injection start date may be modified depending on progress of pre-injection tasks and the Rehabilitation Project.
- Phase 3, Post-Injection: duration of one week, starting the week of October 15, 2012.

A more detailed schedule will be developed following approval of this Work Plan. Implementation of the treatability study activities and demobilization of all equipment is anticipated to be complete by the end of October 2012. These dates are subject to change depending on weather limitations, availability of underground personnel, and progress of the Rehabilitation Project.

7.0 DATA COLLECTION

The field work described in this Work Plan will include water sampling and analysis and field monitoring of water quality parameters. Data collected will be reduced and evaluated to



determine the effectiveness of alkaline injections at the 517 Shaft and the hydraulic characteristics of the mine workings between the 517 Shaft and the St. Louis Tunnel portal.

Sample and data collection will be governed by the task-specific SAP (Appendix A). The SAP is specific to the fieldwork activities that are described in this Work Plan and includes the Field Sampling Plan, a Quality Assurance Project Plan, and related SOPs. The SAP provides guidance for field and laboratory activities, data collection activities, and sample analysis activities so that the data will meet the objectives of the treatability study. The SOPs are included as an attachment to the SAP and establish the procedures, equipment, and documentation that will be used during the treatability study field sampling and measurement activities.

8.0 REPORTING

Test results will be communicated via two mechanisms: (1) regular communications with the project team via teleconference during the field test and (2) preparation of a Treatability Study report with details and interpretation of test results.

During the field test, regular conference calls will be conducted to discuss implementation issues, status of testing, and interim results. Additional calls may be conducted, as necessary, to keep the project team informed of progress and to work through implementation issues that may arise. Key personnel from Atlantic Richfield, U.S. EPA, and CDRMS, as well as their contractor personnel, will be invited to participate in these calls.

After the conclusion of the field study and finalization of all data, a final treatability study report will be prepared and submitted to the U.S. EPA. The report will include a comprehensive description of the treatability study and tracer tests, including a description of the methodology, any deviations from the Work Plan, results of all field monitoring and analytical data, and an interpretation of those results. Data collected will be evaluated to determine the effectiveness of alkaline injections at the 517 Shaft and the hydraulic characteristics of the mine workings. Additionally, previous tracer test results and other characterization data will be discussed, as these data relate to interpretation of the hydraulics of the mine workings and treatability of mine water at the site. Recommendations for future actions will be presented and implications for scale-up will be discussed. The final report will be a key milestone in evaluating mitigation methods for the discharge of mine water from the Rico-Argentine Mine site.



9.0 REFERENCES

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- U.S. EPA, 2011a, Removal Action Work Plan Rico-Argentine Mine Site Rico Tunnels, Operable Unit OU01 Rico, Colorado, EPA Region 8, for Atlantic Richfield Company, March 9, 2011.
- U.S. EPA, 2011b, Unilateral Administrative Order for Removal Action (UAO), Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Docket No. 08-20011-0005, March 23.
- URS, 2012, 2011 Source Water Investigation Report, Rico-Argentine St. Louis Tunnel, Rico, Dolores County, Colorado, March 20, 2012.



TABLES



TABLE 1

BLAINE TUNNEL, 517 SHAFT, AND ST. LOUIS TUNNEL DISCHARGE WATER QUALITY PARAMETERS

Rico-Argentine Mine Site Dolores County, Colorado

Results reported in mg/L

Dissolved Metals	Blaine Tunnel ¹		517	Shaft ²	St. Louis (DR-3)	
Date	8/4/2011	10/3/2011	8/4/2011	10/3/2011	10/20/2011	
рН	NM	2.4	NM	3.2	7.4	
Aluminum	41.3	124	23.6	28.1	0.032	
Cadmium	0.339	0.953	0.285	0.399	0.0175	
Calcium	318	366	332	436	221	
Copper	4.14	15.8	2.25	2.7	<0.005	
Iron	315	1390	46	81.7	1.090	
Manganese	28.2	61.6	17	23.3	2.250	
Sulfate	279	6370	149	1630	53.5	
Zinc	61.7	161	51.5	67.7	3.810	

Notes:

Abbreviations:

mg/L – milligrams per liter NM – not measured

¹ Sample collected from water built up behind the coffer dam within the Blaine Tunnel.

² Sample collected from water within the 517 Shaft approximately 450 feet below the 517 Shaft Access Tunnel.



TABLE 2

BLAINE TUNNEL, 517 SHAFT, AND ST. LOUIS TUNNEL DISCHARGE METALS AND SULFATE LOADING

Rico-Argentine Mine Site Dolores County, Colorado

Loading calculated in kg/d

Dissolved Metals	Blaine Tunnel ¹	517 Shaft ²	St. Louis (DR-3) ³
Date	8/4/2011	8/4/2011	10/20/2011
Aluminum	14.1	9.7	1.4
Cadmium	0.12	0.12	0.21
Copper	1.4	0.9	0.2
Iron	107.8	18.9	1.8
Manganese	9.7	7.0	17.5
Sulfate ⁴	872	1146	2538
Zinc	21.1	21.1	41.9

Notes:

Abbreviations:

gpm - gallons per minute

kg/d - kilograms per day

¹ Sample collected from water built up behind the coffer dam within the Blaine Tunnel. Assumed flow 25 gpm.

² Sample collected from water within the 517 Shaft approximately 450 feet below the 517 Shaft Access Tunnel. Assumed flow 75 gpm.

³ Assumed flow 750 gpm.

⁴ Sulfate concentrations from the October 3, 2011 sample results were used since the reported sulfate concentrations for August 4, 2011 sample results appeared to be biased low.



TABLE 3

BLAINE TUNNEL AND 517 SHAFT CALCULATED CHEMICAL REAGENT DEMAND AND CONSUMPTION

Rico-Argentine Mine Site Dolores County, Colorado

Demand calculated in g/L

Reagent Demand	Blaine Tunnel ¹	517 Shaft ²
Potassium Carbonate	NA	1.15
Sodium Hydroxide	1.0	0.3

Consumption calculated in kg/d

Reagent Consumption	Blaine Tunnel ¹	517 Shaft ²
Potassium Carbonate	NA	471
Sodium Hydroxide	137	123

Notes:

Abbreviations:

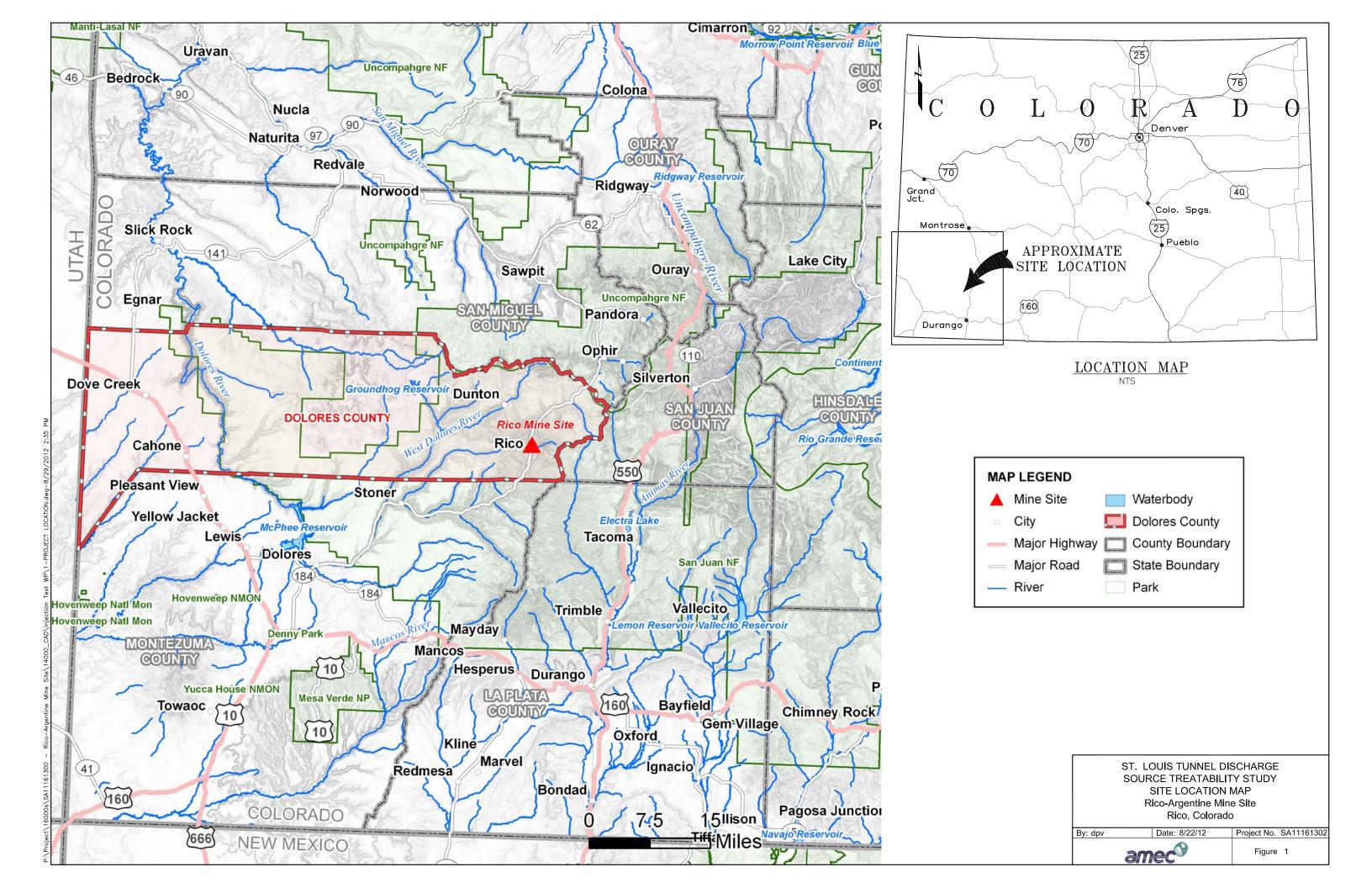
g/L – grams per liter gpm – gallons per minute kg/d – kilograms per day NA – not applicable

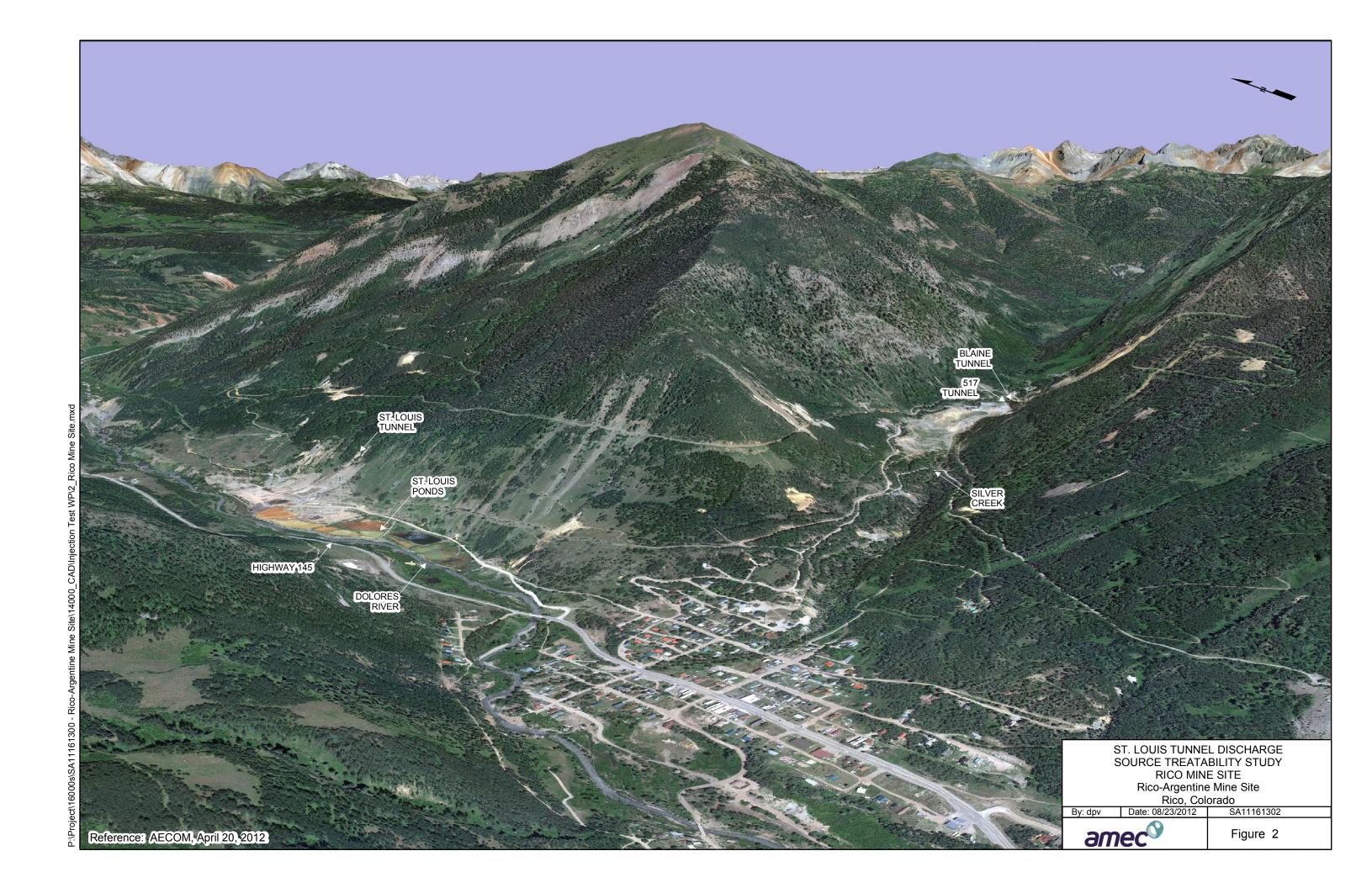
Sample collected from water built up behind the cofferdam within the Blaine Tunnel. Assumed 25 gpm flow.

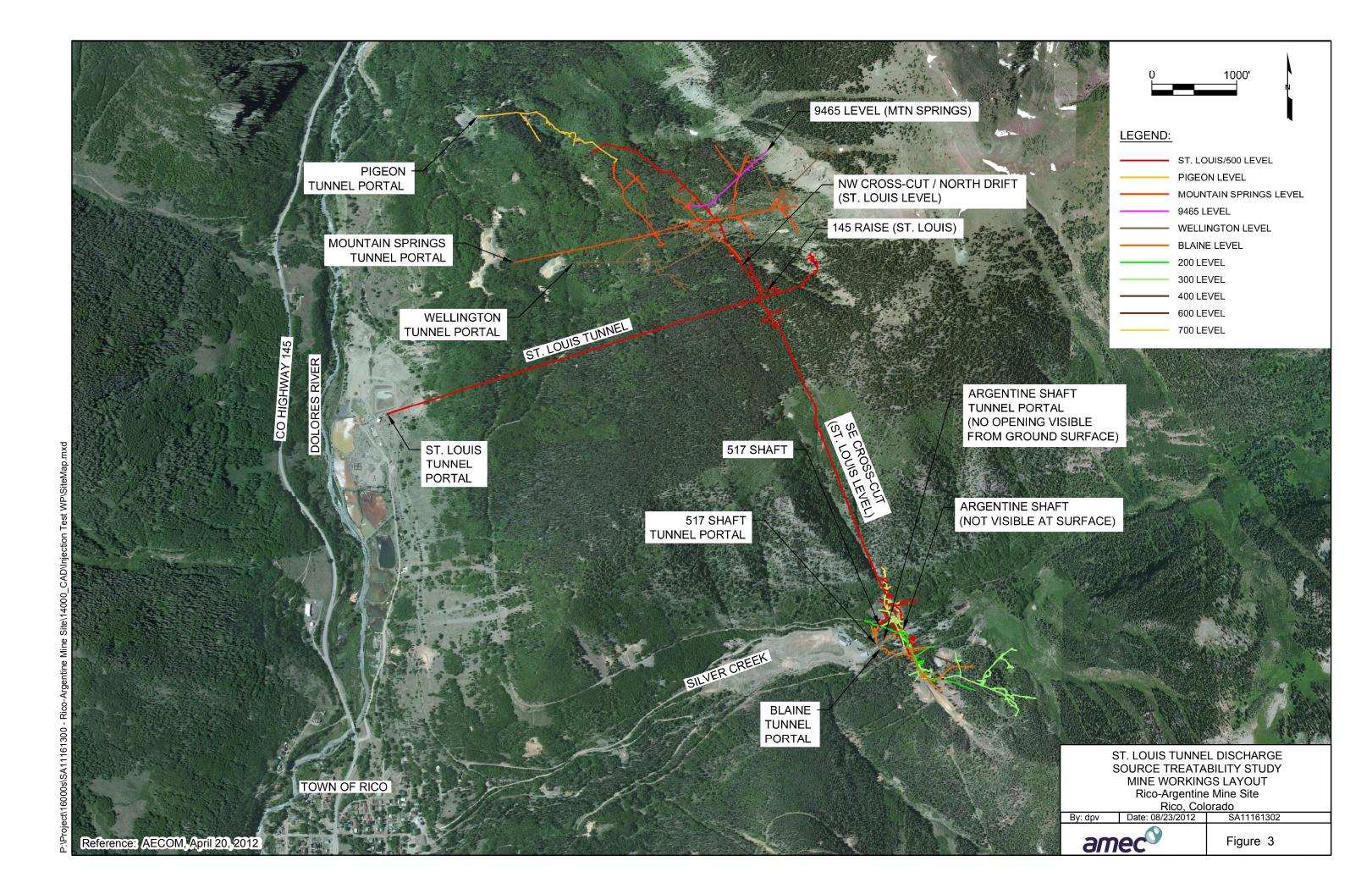
² Sample collected from water within the 517 Shaft approximately 450 feet below the 517 Shaft Access Tunnel. Assumed 75 gpm flow.



FIGURES









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Sampling and Analysis Plan



APPENDIX A ST. LOUIS TUNNEL DISCHARGE SOURCE MINE WATER TREATABILITY STUDY WORK PLAN SAMPLING AND ANALYSIS PLAN Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01 Rico, Colorado

Submitted to:
Atlantic Richfield
La Palma, California

Submitted by:

AMEC Environment & Infrastructure, Inc. Rancho Cordova, California

August 2012

Project No. SA11161301



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Attachment 1 Treatability Study Standard Operating Procedures



APPENDIX A: SAMPLING AND ANALYSIS PLAN ST. LOUIS TUNNEL DISCHARGE SOURCE MINE WATER TREATABILITY STUDY WORK PLAN

Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01 Rico, Colorado

1.0 INTRODUCTION

This Task-Specific Sampling and Analysis Plan (SAP) has been prepared by AMEC Environment & Infrastructure, Inc. (AMEC), on behalf of Atlantic Richfield Company (AR), for the St. Louis Tunnel Discharge Source Mine Water Treatability Study. This study is being conducted to evaluate the treatability of water within the underground workings and the resulting impact on metals concentrations in the St. Louis Tunnel discharge, as described in the main body of this Work Plan. This SAP is task-specific and complements the existing Rico-Argentine Mine Site (site) SAP (Atlantic Richfield, 2012), which was previously submitted to the United States Environmental Protection Agency (U.S. EPA). The existing SAP fulfills a requirement of the Unilateral Administrative Order (UAO) for Removal Action, issued by the U.S. EPA Region 8 on March 17, 2011 for the Rico-Argentine Mine Site (EPA, 2011).

1.1 PURPOSE

This task-specific SAP provides guidance for the fieldwork activities that are described in the Work Plan. It also ensures that the sampling and data collection activities will meet the objectives of the treatability study, while being comparable to and compatible with previous and future investigations. This SAP outlines the field procedures, sampling and data collection activities, and analytical procedures to complete the treatability study tasks.

This task-specific SAP has a limited scope and has been prepared to fulfill the objectives of the St. Louis Tunnel Discharge Source Mine Water Treatability Study described in main body of the Work Plan. This SAP includes a Field Sampling Plan (FSP), a Quality Assurance Project Plan (QAPP), and Standard Operating Procedures (SOPs) for all field activities that will be used to collect samples, measure water quality parameters in the field, and generate data for evaluation of the treatability study. This SAP and its components are therefore task-specific for the treatability study and are intended to complement the existing QAPP (Atlantic Richfield, 2011a) and SAP (Atlantic Richfield, 2012) for the Rico-Argentine Mine Site.



The FSP is included as Section 3 of this SAP and provides guidance for the fieldwork that will be used to complete the tasks and objectives as defined within the Work Plan. The task-specific QAPP (Section 4) establishes the policy, organization, functional activities, and quality assurance and quality control (QA/QC) protocols needed to achieve the decision objectives. The SOPs (included as Attachment 1) establish the procedures, equipment, and documentation that will be used during the field sampling and measurement activities.

1.2 HEALTH, SAFETY, SECURITY, AND ENVIRONMENTAL (HSSE) EXPECTATIONS

All sampling and analysis activities as described in this SAP will be performed in accordance with the Task Specific Health and Safety Plans prepared by AECI and AMEC. The appropriate Risk Assessment, Health and Safety SOPs, and permits will be completed prior to initiating any work described herein.

2.0 OBJECTIVES AND SCOPE

2.1 OBJECTIVES

The objectives of this SAP are as follows:

- Provide guidance for field and laboratory activities, data collection activities, and sample analysis activities so that the results will meet the objectives and tasks of the treatability study;
- Ensure that sampling and data collection activities will be comparable to and compatible with previous data collection activities; and
- Provide a mechanism for planning and approving field activities.

The objectives of the treatability study are described in Section 2 of the Work Plan. This work is intended to support future activities at the site, which will include an evaluation of a range of alternatives for mitigating releases from the mine and implementation of a preferred alternative to complete the removal action.

2.2 SCOPE

This task-specific SAP describes the sampling and measurement methods for the treatability study as described in the Work Plan. The field study will include continuous injection of an alkaline solution to mine water at the 517 Shaft for approximately one month. During the study, water samples will be collected for analysis of various metals and anions, as well as field collection of water quality parameters (e.g., pH, temperature, dissolved oxygen [DO]). All samples to be taken during this field program will be aqueous samples; no gas phase or solid phase samples will be taken. Water samples and measurements will be obtained primarily



from the 517 Shaft injection location and the St. Louis tunnel discharge location, although some samples of injected solutions will also be obtained. Chemical analysis of water samples will be conducted both in the field and at a fixed analytical laboratory.

Analytical data and field measurements that will be collected in accordance with this SAP will be used for the following purposes:

- Evaluate the effectiveness of alkaline treatment of mine water at the 517, with respect to metals concentrations and pH;
- Evaluate the hydraulic characteristics of the Rico-Argentine mine workings between the 517 Shaft injection point and the St. Louis Tunnel Portal; and
- Verify the composition of the materials (tracer solutions and alkaline solutions) injected into the mine water at the 517 Shaft.

3.0 FIELD SAMPLING PLAN

This section presents the Field Sampling Plan for the 517 treatability study. The field test includes the following phases:

- 1. Baseline sampling. Water samples and field measurements taken before any injections will establish the initial conditions.
- 2. Injections. This component consists of an initial short-term injection of conservative tracer and continuous injection of alkaline solution (K2CO3) with a conservative tracer. Tracer data from samples collected at the St. Louis tunnel discharge will be used to evaluate the hydraulic characteristics of the mine workings. Injection of the K2CO3 solution is expected to increase pH and alkalinity, which should result in precipitation of dissolved metals in mine water prior to discharge from the St. Louis tunnel.
- 3. Post-injection. After injections are complete, additional water samples and field measurements will be taken. The purpose of these samples is two-fold: (1) to determine how long the effects of the alkaline injections last, and (2) improve the mass balance on tracers.

The primary indicators of treatment effectiveness will be an increase in pH and a decrease in metals concentrations, with respect to baseline conditions. To determine if these changes occur, samples and data that will be collected during each phase of the field test are similar. The FSP as presented below describes in detail the field measurements and water samples that will be taken, as well as sample locations and sample frequency. The purpose of this task-specific FSP is to ensure consistency and integrity of samples and data that are collected during the 517 treatability study.



Table A-1 summarizes the water samples and field measurements that are to be collected by location, and Table A-2 summarizes the methods, holding times, and preservation requirements for all samples and field measurements.

3.1 SAMPLE LOCATIONS

Samples will be obtained and water quality parameters will be measured at two locations: the 517 Shaft injection location and the St. Louis tunnel discharge (i.e., DR-3). A comparison of data from these two locations will be the primary indicator of treatment effectiveness. Because of accessibility constraints, water samples from the 517 Shaft injection location will only be taken before injections begin (baseline) and after injections are completed (post-injection). In lieu of water samples for chemical analyses, a pH probe will be deployed in the 517 Shaft to continuously measure pH during injections.

3.2 FIELD ACTIVITIES AND SAMPLING

The following paragraphs describe the sampling methods that will be used during the field tests, organized by phase.

3.2.1 Pre-Injection

Pre-injection samples will be used to establish the baseline conditions at the site, prior to initiating pilot-scale treatment. These sample results will be used as the initial conditions for determining the treatment effectiveness.

One pre-injection water sample will be taken from the 517 Shaft injection location using a bailer lowered into the mine water pool. The sample will be obtained from a depth similar to the submerged depth of the injection nozzle. Additionally, a pH probe will be deployed in the 517 Shaft to continuously measure pH. The probe will be submerged at the same depth as the injection nozzle to continuously measure pH before and during injections. pH data will be recorded using an electronic data logger that will take readings and store data at 15-minute intervals; pre-injection placement will yield baseline water quality information. The flow rate will not be directly measured due to inaccessibility and uncertain geometry of the 517 Shaft.

At DR-3, one baseline water sample (grab sample) will be taken prior to injections to establish pre-injection conditions in St. Louis tunnel effluent. A data logging water quality meter will be placed in the water stream to start continuous measurements of water quality parameters (pH, temperature, conductivity, etc.); this device will remain in place at DR-3 throughout the test. Flow rate at DR-3 will be measured using the existing instrumentation.



3.2.2 Injection

This phase includes initial tracer injections and the injection of the K₂CO₃ solution. These sample results will be used to judge the effectiveness of injections and evaluate the hydraulic characteristics of the mine workings.

During injections, no water samples will be taken from the 517 Shaft due to inaccessibility. The pH probe will remain in the mine water pool during injections for continuous pH measurement; changes in pH will be used as an indictor of solution mixing near the injection point. The flow rate within the 517 Shaft will not be directly measured due to inaccessibility and uncertain geometry of the 517 Shaft.

At DR-3, water samples will be taken at 2-hour intervals using an autosampler. The data logging water quality meter will remain in place for continuous measurement of water quality parameters, and the flow rate at DR-3 will be measured using the existing instrumentation at the same intervals as water samples are taken.

3.2.3 Post-Injection

The following samples will be taken after all injections are complete. Post-injection samples and measurements will be used to determine the rate at which water quality parameters return to baseline conditions at each location.

After injections are completed, one water sample will be obtained per day from the mine water pool in the 517 Shaft. These samples will be collected using a bailer submerged to the same depth as previous samples from this location. The pH probe will remain in place for one week after injections are completed. As before, the flow rate will not be directly measured at this location due to inaccessibility and uncertain geometry of the 517 Shaft.

Post-injection effluent samples from the St. Louis tunnel discharge will continue to be taken at 4-hour intervals using the autosampler for one week after injections are complete. Water quality parameters will continue to be measured during this period. Flow rate will be measured at the same time as samples are taken using the existing instrumentation.

3.3 FIELD MEASUREMENTS

Table A-2 summarizes the parameters that will be measured in the field, and the associated SOPs (Attachment 1) provide details of field measurement and analytical methods. The following parameters will be measured in the field with calibrated field instrumentation:

pH;



- Conductivity;
- Temperature;
- Oxidation-reduction potential (ORP); and
- Dissolved oxygen (DO).

Additionally, the flow rate will be measured at the St. Louis tunnel discharge using the existing flow measurement device.

The following analytes will be measured in the field, using spectrophotometer methods:

- Alkalinity;
- · Chloride; and
- Zinc.

Additionally, bromide will be measured at the St. Louis tunnel discharge using an ion-specific electrode to monitor the peak bromide concentrations in response to the initial pulse injection of sodium bromide. Measurement of these parameters in the field will allow near real-time evaluation of treatment effectiveness, which will assist in decision making during the pilot study.

3.4 LABORATORY ANALYTICAL METHODS

Table A-2 summarizes the laboratory analytical methods that will be used for each parameter, and the QAPP (Section 4) further describes the laboratory QA/QC requirements for these analyses.

3.5 SAMPLE DESIGNATIONS

The unique sample designations to be used during the treatability study are defined in this section. To maintain organization of data, sample identification numbers will include a sample location identifier. The sample date and time will be recorded and used to correlate to the phase of the study (pre-injection, injection, or post-injection). Location identifiers for samples will be as follows:

Injection Line – Location identifier is "517 Inject".



<u>517 Injection Point</u> – The location identifier for the 517 Shaft will include the depth at which samples are taken. For example, if a sample is taken from 450 feet below the shaft collar, the location identifier will be "517Shaft450".

<u>St. Louis Tunnel Discharge</u> -- Location identifier is "DR3", which corresponds to the established surface water sampling station.

As an example, a sample taken on 21 September 2012 from the St. Louis tunnel discharge will be designated as "DR3120921.

Sample containers will be labeled with self-adhesive labels, with all necessary information filled out using waterproof ink. At a minimum, each sample label will contain the following information:

- project name;
- site location;
- sample identification code;
- date and time of sample collection, with sampler's initials;
- analyses required;
- method of preservation, if used; and
- · sampler's initials.

3.6 SAMPLE HANDLING

The sample handling and analysis procedures are described SOP 1, included in Attachment 1. Examples of paperwork included in the SOP include chain-of-custody forms, sample logs, and sample labels. Table A-2 identifies the required sample volumes, sample preservation methods, types of sample containers, packing and shipping requirements, sample designation requirements for the project database, documentation requirements, and holding times.

4.0 QUALITY ASSURANCE PROJECT PLAN

Atlantic Richfield's Quality Assurance Project Plan for Surface Water Monitoring at the Rico-Argentine Mine Tunnels (Atlantic Richfield, 2011a) addresses the quality assurance and quality control procedures for conducting environmental sampling in surface water at the site that are consistent with the U.S. EPA's Quality Assurance/Quality Control Guidance for



Removal Activities (U.S. EPA, 1990). For this treatability study, the sampling and analysis activities conducted by AMEC will be in general accordance with these procedures.

AMEC has developed task specific SOPs (Attachment A-1) to describe field procedures for monitoring surface water and collecting samples for testing purposes. Table A-1 summarizes sample collection and analyses to be employed prior to and during the injection activities. Field analyses during the described activities will be conducted in "real-time" and data recorded in electronic format for evaluation and decision making. Samples collected for off-site laboratory testing will be sent to Pace Analytical Lab in Lenexa, Kansas, an accredited environmental testing laboratory through the National Environmental Laboratory Accreditation Program (Kansas NELAP Certificate No. E-101116), using proper chain of custody procedures and USEPA approved methodologies presented in Table A-2. The laboratory will adhere to the additional quality control requirements set forth in Atlantic Richfield's Technical Requirements for Environmental Laboratory Services (Atlantic Richfield, 2011b) which provides quality standards for contracted laboratories performing work for Atlantic Richfield. Laboratory results will be provided to AMEC for data verification and evaluation of the effectiveness of the injection activities.

5.0 STANDARD OPERATING PROCEDURES

The SOPs (included as Attachment 1) establish the procedures, equipment, and documentation that will be used during the field sampling, data measurement, and analytical activities for the 517 treatability study. These SOPs cover aspects of the treatability study related to sampling, sample handling, documentation, and field measurement methods. These SOPs will be followed during field activities to ensure that all activities are completed consistently and properly documented.



6.0 REFERENCES

- Atlantic Richfield, 2011a. Quality Assurance Project Plan for Surface Water Sampling, Rico-Argentine Mine Site Rico Tunnels Operable Unit OU01, Rico, Colorado. Submitted to U.S. EPA Region 8. 20 June 2011.
- Atlantic Richfield, 2011b. Technical Requirements for Environmental Laboratory Services BP Laboratory Management Program, Revision 10. December.
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- United States Environmental Protection Agency (U.S. EPA), 2011. Unilateral Administrative Order for Removal Action, Rico-Argentine Site, Dolores County, Colorado. Docket No. CERCLA-08-2011-0005. 17 March 2011.



TABLES



TABLE A-1 FIELD SAMPLING PLAN SUMMARY SAMPLING AND ANALYSIS PLAN

Rico-Argentine Mine Site Rico, Colorado

Phase	Location	Estimated Duration (days)	Sample Frequency	Estimated Number of Samples	Sampling Method	Analyses	Rationale
Baseline/Pre-Injection	517 Shaft Injection Zone		1 sample	1	Bailer	Field Measurements (1); Field Analytical (2); Lab (3); Lab (4)	Baseline conditions at injection point
	Silver Creek		1 sample	1	Grab	Field Measurements (1); Lab (3); Lab (4)	Characterize dilution water
	Injection Line		none	0	N/A	N/A	No injection solution to sample
	St. Louis discharge DR-3		1 sample	1	Grab	Flow Rate; Field Measurements (1); Field Analytical (2); Lab (3); Lab (4)	Baseline conditions at St. Louis discharge point
Injection (K ₂ CO ₃) Step 1	517 Shaft Injection Zone	7	0	0	N/A	N/A	No sampling due to inaccessbiilty during injections
	Silver Creek		0	0	N/A	N/A	Assumes Silver Creek dilution water is consistent.
	Injection Line	7	1 sample, after injection starts	1	Open & purged sample port	N/A	Verify composition of injection solution
	Ct. Lauria diasharas DD 2	7	3 samples per day (5)	21	Grab or Autosampler	Field Measurements (1); Field Analytical (2); Lab (3)	Evaluate effects of injections
	St. Louis discharge DR-3	/	12 samples per day	84 (a)	Autosampler	Flow rate; Lab (4)	Monitor tracer study constituents
Injection (K ₂ CO ₃) Step 2	517 Shaft Injection Zone	7	0	0	N/A	N/A	No sampling due to inaccessbiilty during injections
	Silver Creek		0	0	N/A	N/A	Assumes Silver Creek dilution water is consistent.
	Injection Line	7	1 sample, after injection starts	1	Open & purged sample port	N/A	Verify composition of injection solution
	St. Louis discharge DR-3	7	3 samples per day (5)	21	Grab or Autosampler	Field Measurements (1); Field Analytical (2); Lab (3)	Evaluate effects of injections
	St. Louis discharge DR-3	/	12 samples per day	84 (a)	Autosampler	Flow rate; Lab (4)	Monitor tracer study constituents
Injection (K ₂ CO ₃) Step 3	517 Shaft Injection Zone	7	0	0	N/A	N/A	No sampling due to inaccessbiilty during injections
	Silver Creek		0	0	N/A	N/A	Assumes Silver Creek dilution water is consistent.
	Injection Line	7	1 sample, after injection starts	1	Open & purged sample port	N/A	Verify composition of injection solution
	St. Louis discharge DR-3	7	3 samples per day (5)	21	Grab or Autosampler	Field Measurements (1); Field Analytical (2); Lab (3)	Evaluate effects of injections
	St. Louis discharge DK-3	,	12 samples per day	84 (a)	Autosampler	Flow rate; Lab (4)	Monitor tracer study constituents
Injection (K ₂ CO ₃) Step 4	517 Shaft Injection Zone	7	0	0	N/A	N/A	No sampling due to inaccessbiilty during injections
	Silver Creek		0	0	N/A	N/A	Assumes Silver Creek dilution water is consistent.
	Injection Line	7	1 sample, after injection starts	1	Open & purged sample port	N/A	Verify composition of injection solution
	St. Louis discharge DR-3	7	3 samples per day (5)	21	Grab or Autosampler	Field Measurements (1); Field Analytical (2); Lab (3)	Evaluate effects of injections
	St. Louis discharge DR-3	,	12 samples per day	84 (a)	Autosampler	Flow rate; Lab (4)	Monitor tracer study constituents
Post-Injection	517 Shaft Injection Zone	7	1 sample per day	7	Bailer	Field Measurements (1); Field Analytical (2); Lab Analytical (3)	Characterize post-injection conditions
	Silver Creek		None	0	N/A	Field Measurements (1); Field Analytical (2); Lab Analytical (3)	Not needed after injections solutions prepared
	Injection Line		None	0	N/A	N/A	No injection solution to sample
	St. Louis discharge DR-3	7	2 samples per day (5)	14	Grab or Autosampler	Field Measurements (1); Field Analytical (2); Lab (3)	Evaluate effects of injections
	St. Louis discharge DR-3	′	6 samples per day	42 (a)	Autosampler	Flow rate; Lab (4)	Monitor tracer study constituents

Notes/Abbreviations:

- (1) Field measurements consist of pH, temperature, conductivity, ORP, and DO using calibrated instrumentation.
- (2) Field analytical consists of ion-specific electrode measurement of bromide (to monitor pulse tracer injection output only), and photometer measurements of zinc, alkalinity, and chloride.
- (3) Lab Analyses: total and dissolved metals; alkalinity; and sulfate using methods shown in Table A-2.
- (4) Lab Analyses (tracers): chloride, bromide, fluoride, lithium, sodium, and/or potassium using methods shown in Table A-2; specific tracer ions to be analyzed dependent on what tracers are used.
- (5) Sample frequency and/or analyte list may be reduced, based on evaluation of tracer results and system response to alkaline solution injection.

(a) Lab will be directed to analyze every sixth sample (4 samples per 24-hour sampling period), and to put remaining samples on hold. AMEC will provide direction to lab on additional samples to analyze, based on initial sample results.

DO = dissolved oxygen N/A = not applicable K_2CO_3 = potassium carbonate NaOH = sodium hydroxide ORP = oxidation reduction potential



TABLE A-2 METHODS, HOLDING TIMES, AND PRESERVATION REQUIREMENTS SAMPLING AND ANALYSIS PLAN

Rico-Argentine Mine Site Rico, Colorado

Parameter	Method Reference	Container	Suggested Volume ¹	Preservation ²	Estimated Detection Limit	Maximum Holding Time
			Laboratory A	nalyses		
Total and Dissolved Metals ³	EPA 200.7/200.8	Р	500 mL	HNO ₃ to pH<2; Field filtered for dissolved metals	0.5 - 50 ug/L	6 months
Alkalinity (as CaCO ₃) - Bicarbonate alkalinity - Carbonate alkalinity -Hydroxide alkalinity	SM 2320B	Р	300 mL	None	20 mg/L	14 days
Bromide	EPA 300.0	Р	100 mL	None	1 mg/L	28 days
Chloride	EPA 300.0	Р	100 mL	None	1 mg/L	28 days
Fluoride	EPA 300.0	Р	100 mL	None	1 mg/L	28 days
Sulfate	EPA 300.0	Р	100 mL	None	1 mg/L	28 days
			Field Measu	rements		
Flow Rate	Field SOP 6.0	Р	N/A	None	0.1 feet/second	None
рН					0.1 unit	15 minutes
Conductivity					0.1 μS/cm	15 minutes
Temperature	Field SOP 3.0	Р	100 mL	None	0.15 °C	15 minutes
Oxidation Reduction Potential					0.1 mV	15 minutes
Dissolved Oxygen					0.2 mg/L	15 minutes
Alkalinity	Field SOP 03	Р	50 mL	Field filtered	25 mg/L	24 hours
Bromide ⁴	Field SOP 03	Р	50 mL	Field filtered	5 mg/L	28 days
Chloride	Field SOP 03	Р	50 mL	Field filtered	5 mg/L	28 days
Zinc	Field SOP 03	Р	100 mL	Field filtered; HNO ₃ to pH<2	0.02 mg/L	6 months

Notes/Abbreviations:

- 1 Additional volume may be provided for laboratory QC samples (e.g., matrix spike, laboratory duplicate).
- 2 Samples should be stored at a temperature ranging from 0°C 6°C, or analyze immediately.
- 3 Metals: Ca, Fe, K, Li, Na, Mg, and Zn (200.7) and As, Cd, Co, Cr, Cu, Mn, Ni, Pb, and Se (EPA 200.8)
- 4 Bromide to be analyzed by ion-specific electrode.

 $CaCO_3$ = calcium carbonate

P = Polyethylene



ATTACHMENT 1

Standard Operating Procedures



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1.0 - FIELD DOCUMENTATION AND SAMPLE HANDLING

Purpose and Scope: The purpose of this document is to present procedures for field

documentation and sample handling. It includes a description of how to fill out a Daily Field Record (DFR), Sample Control Log, and Chain-of-Custody (COC). It also describes procedures for sample labeling,

handling, preservation, packaging, and shipping.

Equipment: The following equipment will be needed depending on specific task and will be used, as appropriate, when packing or shipping samples:

Sample Bottles

Sample Labels

Custody Seals

Fine Tipped Permanent Markers

Nitrile gloves or other appropriate gloves

Sealable storage bags

Bubble wrap or appropriate packing materials

Blue ice or double bagged ice

Coolers suitable for sample shipment and holding ice

Strapping/packaging tape and shipping labels, if needed

Camera with spare memory chip and batteries

Documentation: DFR (attached)

Sample Control Log (attached)

COC Document (attached) or laboratory equivalent

Sampling Records Maps/plot plan

Camera

Photograph Log (attached)

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plans (SAPs).

1.1 FIELD AND SAMPLE DOCUMENTATION

Documentation of the conditions and procedures used to collect, treat, and handle samples and field data is one of the most important aspects of any sampling or monitoring program. Proper documentation provides sources to determine the integrity and applicability of the data. Carefully document all field activities in a field logbook or on data sheets. Field logbooks shall be bound with consecutively numbered pages and shall be written in with permanent black ink. All field logbooks will be dedicated to the Rico-Argentine Project. At the end of each field season, the original field log books and all original data sheets will be kept in the AMEC office,

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located in Rancho Cordova. Field activities shall be recorded in sufficient detail so that field activities can later be reconstructed from the notes. Any changes to the notes in the field logbook shall be made by drawing a single line through the incorrect material and initialing and dating the mark-out.

1.1.1 Daily Field Record (DFR)

Documentation of observations and data acquired in the field provide information on sample acquisition, field conditions at the time of sampling, and a permanent record of field activities. Record field observations and data collected during the investigation with waterproof ink on DFR sheets (Attached). A new DFR should be completed for each day or when a separate phase of work is initiated.

The DFRs will include the following information, as appropriate.

- Project and Task Number
- Project Name
- Location of sample (if samples are collected)
- Date
- Time
- Field Activity
- Weather Conditions
- Personnel Onsite, Company Name, and Time Onsite
- Personal Safety Checklist
- Description of Work Performed
- Description of Waste Generated

Information written within the area delineated "Description of Work Performed" should include the following:

- Sample identification number(s)
- Time of sample
- Description of sample
- Number and volume of samples



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- Field observations
- List other associated paperwork related to the activity (e.g., boring log, sample control log, maps, etc.)
- Decontamination procedures

Photographs should be taken of pertinent activities that occur during the investigation. These should include capturing images that clearly demonstrate that the goals of the project are being met. They should also be taken of any changes in procedures or unexpected findings that occur in the field. Items of scale should be included in the view of the photograph (i.e., ruler, clipboard, etc.). A running log of the photographs with a description of each photograph should be included on a photo log attached to the DFR. All photos should include the following information on the photo log: ID number generated by the camera, date the photo was taken, initials of the photographer, location of the photo, direction of view and any additional comments or descriptions.

Strike out changes or deletions in the field book or on the data sheets with a single strike mark and be sure that the original information remains legible. Each page should be completely filled without any blank lines, if necessary write "Not Applicable" or "NA" on blank lines. The field logbook or field data sheets should be signed daily by the author of the entries.

1.1.2 Sample Control Log

If samples are collected during the field investigation, a sample control log must be filled out documenting the sample location, study area, sample matrix, sample ID, sample date, sample time, sample collector, sample depth, sample type, code (whether the sample is a normal environmental sample or which type of quality assurance/quality control [QA/QC] sample it is), additional notes (i.e. sample turnaround time, COC remarks, details about the sample or analysis, etc.), which laboratory the samples were sent to and the date they were shipped.

1.1.3 Chain of Custody (COC)

During sampling activities, a "paper trail" of sample custody must be maintained from the time the samples are collected until laboratory data are issued. Information on the custody, transfer, handling, and shipping of samples should be recorded by the sampling personnel on an Atlantic Richfield COC form. If an project or task-specific COC form is not available (i.e., with specific analytes and analytical methods listed), an equivalent form provided by the destination



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laboratory can be used instead. A COC form will be completed for each set of samples collected daily. At a minimum, every COC will contain the following information:

- Sampling Personnel's name and signature
- Project name
- Date and time of collection
- Sample identification number and matrix
- Analyses requested
- Number of containers and any preservative used
- Signature of persons relinquishing custody, dates, and times
- Signature of persons accepting custody, dates, and times
- Method of shipment
- Shipping papers/waybill identification number (as appropriate)

Atlantic Richfield sponsors the Laboratory Management Program (LaMP). The LaMP consists of a network of approved contract laboratories that supply analytical testing services for Atlantic Richfield's environmental and remediation programs. The LaMP was implemented to ensure that the analytical testing and services needs of Atlantic Richfield Company are consistently met on environmental/remediation projects. The LaMP provides and assures sources of high quality analytical data for Atlantic Richfield that are legally defensible and minimizes the total cost of ownership. COCs for samples shipped to an Atlantic Richfield contract laboratory will contain the following information:

- Name of the lead regulatory agency
- Name and contact information of the environmental business manager
- Name and contact information of the consultant and Project Manager
- Enfos proposal number and the stage and activity level of the project
- Level of data package requested



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An example COC is provided as an attachment and should be strictly followed as it is important that COCs are completed with consistent information. A copy of each COC form will be retained in the project files.

1.1.4 Sampling Records

Sampling records have been customized for each type of sampling (groundwater from a well, grab groundwater from a boring, surface water, storm water and storm sediment). The associated sampling record should be filled out during the sampling process. Pertinent information varies with each type of sampling, but at a minimum, the following information should be filled out for each sample:

- Sample identification number(s)
- Time of sample
- Results of any field measurements, such as depth to water, pH, temperature, specific electrical conductivity, dissolved oxygen, turbidity, discharge, etc
- Any QA/QC samples that were collected
- Field observations, such as color, odor or texture of the sample, etc.
- Method of sampling
- Name and signature of sampler

1.2 SAMPLE LABELING

After sample collection, the samples will be labeled with self-adhesive labels with all necessary information added using waterproof ink. Make sure the labels are completed so that the information is legible and consistent. At a minimum, each sample label will contain the following information:

- Project name
- Study Area or Task
- Sample identification code
- Date (mmddyy) and military time (tt:tt) of sample collection
- Analyses required
- Method of preservation, if used
- Sampler's initials



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The information on the sample label shall match the COC.

Each sample, including QA/QC samples, will be assigned a unique identification code according to sample location, date, and depth (if applicable). For example, if a sample is collected from the 517 Shaft at a depth of 450 feet below the shaft collar on August 20, 2012, the sample ID will be "517Shaft450" 120820".

Field blanks and duplicates shall be labeled so that the sample location is not identified to the lab. For example, if a duplication sample is collected from the 517 Shaft on August 20, 2012, the sample ID will be "Dup_120820". The identity of field QC samples will be traceable through the sample control log.

1.3 SAMPLE HANDLING

General sample handling procedures shall include the following:

- Always make field measurements on a separate sub-sample, not on the sample that
 is sent to the laboratory for analysis. Discard the sub-sample after the
 measurements have been made.
- Do not use containers that have been used in the laboratory to store concentrated reagents or have been previously used as sample containers. Use only new containers that are certified clean by the manufacturer or laboratory for sample collection.
- For water samples, do not allow the inner portion of sample containers and caps to come into contact with bare hands, gloves, tubing or other objects.
- Keep sample containers in a clean environment away from dust, dirt, and fumes.
 Field personnel shall wear disposable nitrile gloves when collecting water samples.
 Gloves must be changed out between each water sample collected.
- Do not let any samples, including water, vegetation, or invertebrate samples, stand in the sun. Store all samples in coolers with blue or double bagged ice;
- COC procedures will be strictly adhered to during sample collection, transportation, and laboratory handling to assure the identity of the samples. Improper sample and data handling and inadequate COC procedures affect the credibility and acceptability of analytical results, regardless of their accuracy or precision. COC documentation will document processing of the sample from the time of collection to the time of analysis.

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If overnight storage of collected water samples is required prior to shipment to a laboratory, the samples will be stored in accordance to procedures described in Section 1.6.

1.4 SAMPLE PRESERVATION

Sample preservation will depend on the analytical method to be performed and the sample matrix. Preservation methods and preservatives for each analytical method and matrix will be presented in the associated SAP. The planned sample preservation activities, sample container size and type, and analytical methods should be confirmed with the laboratory well in advance of collecting samples.

For all water samples, the laboratory will supply clean, unused, and pre-preserved sample containers as appropriate. If containers are preserved, the type of preservative should be clearly labeled on each bottle. Do not rinse out sample containers. The preservative will be documented on the sample label and COC. Soil samples collected in non-laboratory certified clean containers (e.g., via split spoon, direct push or drive method), will be decontaminated prior to use in accordance to procedures described in SOP 04, Equipment Decontamination.

1.5 SAMPLE PACKAGING AND SHIPPING

If samples are required by the laboratory to be chilled, they will be stored during the day in icecooled containers.

Samples collected during the morning may be temporarily stored in a refrigerator (if available) until shipment in the afternoon. All samples stored in the coolers or the refrigerator will be documented on the sample control log. When samples are being packaged for shipment, the procedures listed below will be followed.

- Field personnel will visually screen each sample in the cooler for loose surface contamination, and confirm that each sample is listed on the sample control log and the COC.
- 2. Samples will be packed with abundant packaging material to minimize the potential for damage during shipment. If samples need to be chilled, they will be double-bagged in sealable plastic bags and immediately placed on ice in an insulated cooler. Insulated coolers will be provided by the contract laboratories. Sample containers will be placed right side up in a cooler with double bagged ice for delivery to the laboratory.



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- 3. The completed COC will be scanned and emailed to the lab to inform them about the sample(s) they will be receiving. The scans will be saved for project records. Then, the COC will be signed and placed in a plastic sealable storage bag which will be taped to the inside cover of the cooler. The COC form will be shipped with the cooler to confirm transfer; the carrier waybill number will be recorded on the original COC. Commercial carriers are not required to sign the COCs. However, we do need to sign over custody to the courier (if using a courier to deliver the samples to a commercial carrier) and have the courier sign over custody for the approximate time he will relinquish the samples. The lab will sign for "Accepted" when they open the cooler.
- 4. If samples are to be transported overnight via Federal Express or United Parcel Service, all ice must be double bagged to prevent leakage. The lid of the cooler must be taped shut with custody seals. The cooler will then be taped shut using clear shipping tape. Failure to seal all potential leaks may result in rejection of delivery by the courier. If samples are shipped on a Friday then Saturday delivery stickers must be attached to the coolers on all four sides as well as the top. Make sure to check the overnight delivery space on the shipping papers. Affix the label on the top or side of the cooler.
- 5. Samples will typically be shipped to the laboratory daily. Copies of the completed COC will be kept in the field office by the field manager.
- 6. Sample shipment will be scheduled to prevent exceeding any required holding period. Failure to conduct analyses within the required holding times may potentially require the qualification of associated analytical results and will prompt appropriate corrective and preventive action measures.

1.6 OVERNIGHT STORAGE

If the hold time allows, samples may be stored overnight as long as they are properly packaged, labeled, placed in a secure location. If chemical analysis is to be performed on the sample, it must be stored at no more than 4°C or 39°F, but above freezing. Samples will be kept in a cooler or refrigerator locked in a secure location and shipped the following day. When placing samples into the refrigerator, make sure it is plugged in and turned on and set at the appropriate temperature. Samples should not be kept for more than a week. If samples are kept overnight, chain of custody procedures must still be followed.

1.7 REVISION LOG

Revision	Author	Description of Change (Section number)	Date
Number			

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ATTACHMENTS

- Daily Field Record (DFR)
- Sample Control Log
- Atlantic Richfield Chain-of-Custody (COC) Record
- Photograph Log



DAI	LY FIE	ELD RECORD)								
Project	and Tasl	k Number:			Date:						
Project	Name:				Field Activity:						
Location	n:				Weather:						
PERSO	ONNEL:	Name			Company			Time In	Time Out		
		PERS	SONAL	SAFETY	CHECKLIST						
	Safety-te	oed Boots		Hard Hat			Radio				
	Nitrile/Le	eather Gloves		Safety GI	asses		Ear Pl	ugs			
DRU	IM I.D.	DESCRIPTION	ON OF	CONTENT	S AND QUANITY			LOCATION	ON		
TI	ME		İ	DESCRIPTI	ON OF WORK PER	RFORM	ED				

Page 1 of ____



DAILY FIELD RECORD (continued)								
Project and Tasl	Number:	Date:						
TIME	DESCRIPTI	ON OF WORK PERFORMED						

Page ___ of ___



SAMPLE CONTROL LOG

Project Name:	Task Name:	
Project & Task No.:	Week of:	_Crew:

Sample Location	Sample Matrix	Sample ID	Sampling Date	Sample Time	Sample Collector Initials	Sample Depth (feet bgs)	Sample Type ¹ Code ²	Additional Notes ³	Lab	Date Sent to Lab
						(*************************************	Code			

- 1. Sample Types include: Grab, Composite, Incremental, or Autosampler
- 2. Code includes: Normal Environmental (NE), Field Duplicate (FD), Field Blank (FB), Equipment Blank (EB), and Matrix Spike/Matrix Spike Duplicate (MS/MSD)
- 3. Include notes such as: turnaround time, sample location details, handling notes, Chain-of-Custody remarks, etc.



Laboratory Management Program LaMP Chain of Custody Record

	ompany A BP affiliated company	BP/ARC Pro	oject Name: cility No:																/dd/yy ımbeı	_					Rush TAT:	Yes	_ No
Lab Na				BP/	ARC	Facili	ity Ac	ldress	s:										Consu	ultant/	Contra	ctor:					
Lab Ac	ddress:			City	, Sta	te, ZIF	P Cod	de:											Consu	ultant/	Contra	actor F	Projec	et No:			
Lab PN				Lea	d Re	gulato	ory A	gency	' :										Addre	ss:							
Lab Ph	none:			Cali	ifornia	a Glol	bal ID	No.:											Consu	ultant/	Contra	ctor F	PM:				
Lab Sh	nipping Accnt:			Enfo	os Pr	oposa	al No	:											Phone	ə:							
Lab Bo	ottle Order No:			Acc	ounti	ng Mo	ode:		Pro	vision		OC	C-BU		000	C-RM			Email	nail EDD To:							
Other	Info:			Stag	ge:				Α	ctivity:									Invoic	e To:		BP/	ARC		Contractor		
BP/AR	C EBM:				Ma	itrix		No	o. Co	ntain	ers /	Pres	ervat	ive			F	Requ	ested	Ana	lyses				Report Ty	pe & QC L	.evel
EBM F	Phone:							S																	Sta	ındard	_
EBM E	Email:							ainer																	Full Data Pa	ckage	-
Lab No.	Sample Description	Date	Time	Soil / Solid	Water / Liquid	Air / Vapor		Total Number of Containers	Unpreserved	H ₂ SO ₄	HNO ₃	HCI	Methanol												Cor Note: If sample not o Sample" in comment and initial any prepri	ts and single-	strike out
																					_						
				-					-											-							
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Sampl	er's Name:				<u> </u>	F	Relin	quis	hed	By / A	Affilia	tion			Da	ite	Tir	ne			Acce	epted	Ву	/ Affi	liation	Date	Time
	er's Company:							•														•					
	ent Method:	Ship Date:		1																							
	ent Tracking No:			T																							
Speci	ial Instructions:			1																							
	THIS LINE - LAB USE ONLY: Cu	stody Seals In Pla	ice: Yes / No		Tem	p Blaı	nk: Y	es / N	0	С	ooler	Temp	on Re	ceipt:			_°F/C		Trip	Blank	k: Yes	/ No		MS/	MSD Sample Subm	nitted: Yes /	No
	= = = = = = = = = = = = = = = = =																								mer eample each		

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PHOTOGRAPH LOG

Project Name:					Task Name:
Project & Task No.:					Camera No:
Camera Assigned ID #	Date	Photographer Initials	Location	Direction of View	Additional Comments



Standard Operating Procedures
Sample Collection and Data Collection Techniques

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2.0 – SAMPLE COLLECTION TECHNIQUES AND DATA COLLECTION STRATEGIES

Purpose and Scope: The purpose of this document is to describe general sampling

techniques and data collection strategies.

Equipment: Nitrile gloves or other appropriate gloves

Measuring Wheel or Tape Measure

Flag markers

Hand-Held Global Positioning System (GPS) device;

Camera Marking flags Marking paint

Documentation: Daily Field Record (DFR)

Photo Log Maps

This Standard Operating Procedure (SOP) is to be used in conjunction with a Sampling and Analysis Plan (SAP) and applicable work plans. Specific sample techniques, strategies, locations and frequency will be presented in the work plans. However, in the event that the work plans require that sample collection techniques and data collection strategies must be determined in the field (e.g. pre-investigation planning, mapping, waste sampling), the procedures within this SOP should be followed.

2.1 SAMPLE COLLECTION TECHNIQUES

Three basic types of sample collection techniques will be used: Grab and Composite Samples. These techniques are described below:

- A grab sample is defined as a discrete sample representative of a specific location at
 a given point in time. The sample is collected all at once at one particular point in the
 sample medium. The representativeness of such samples is defined by the nature of
 the materials being sampled. In general, as sources vary over time and distance, the
 representativeness of grab samples will decrease.
- A composite sample is a non-discrete sample composed of more than one sample
 collected at various sampling locations and/or different points in time. Analysis of
 this type of sample produces an average value and can in certain instances be used
 as an alternative to analyzing a number of individual grab samples and calculating an
 average value. It should be noted, however, that compositing can mask problems by
 diluting isolated concentrations of some hazardous compounds below detection
 limits.

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 Incremental sampling (IS) is a structured composite sampling protocol that reduces sampling error associated with compositional and distributional heterogeneity of the analyte of interest in soil or sediments. The IS protocol consists of defining sampling or decision units, collecting a minimum of 30 individual soil samples from randomly selected locations within each unit, and submitting the samples to the laboratory for processing (drying, compositing, sieving, and sub-sampling) in a specified manner prior to laboratory analysis.

2.2 DATA COLLECTION STRATEGIES

The number of samples that should be collected and analyzed depends on the objective of the investigation. There are three basic sampling strategies: random, systematic, and judgmental sampling. Each of the strategies is explained in the following:

- Random sampling involves collection of samples in a nonsystematic fashion from the entire site or a specific portion of a site.
- Systematic sampling involves collection of samples based on a grid or a pattern which has been previously established.
- Judgmental sampling involves collection of samples only from the portion of the site most likely to be contaminated.

A combination of these strategies is the best approach depending on the type of the suspected/known contamination, the uniformity and size of the site, and the level/type of information desired.

2.3 SAMPLE LOCATION DOCUMENTATION

Once a sample location is chosen and the sample has been collected, the location will be temporarily staked or marked until it has been surveyed. Additionally, 3 to 4 photos of the location should be taken so the location is well documented. The photos should be documented on a photo log (SOP 1.0 – Field Documentation and Sample Handling).

Wooden stakes, steel fence posts with safety caps, survey whiskers, pin flags with the name of the location written in permanent marker, or survey whiskers can be driven into the ground to show the location. It is not recommended that spray paint be used to mark locations as it may get washed off or brushed over by dirt and rocks. Spray paint may be used as a temporary location marker; however, the spray paint marker should either be surveyed or replaced as soon as possible so the location is not lost.



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For samples and activities that require high accuracy survey data such as the installation of borings for subsurface mapping, the installation of monitoring wells and piezometers for water level measurement, and the installation of surface monitoring monuments, survey activities will be subcontracted to a third party that has a current California survey license and is capable to surveying within a 100th of a foot. All surveys shall be completed using the most recent version of the State Plane Coordinate System. The surveyor will obtain accurate coordinates and elevations of the sample locations within several weeks after the installation activities.

If only sub-meter accuracy for vertical and horizontal survey information is needed, a hand-held GPS device may be used in place of a licensed surveyor to obtain general coordinates of locations and activities.



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1.4 **REVISION LOG**

Revision Number	Author	Description of Change (Section number)	Date



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3.0 - FIELD MEASUREMENTS - WATER

Purpose and Scope: The purpose of this document is to provide procedures for measuring

the water levels from wells and collecting field parameters in surface water and groundwater. It includes instructions on the setup, field

procedures, and how to fill out the associated field forms.

Equipment: pH Meter and Electrode

Specific Electrical Conductance (SEC) Meter

Dissolved Oxygen (DO) Meter

Oxidation Reduction Potential (ORP) Meter

Thermometer or Temperature Probe

Fluorometer

Fluorometer Sample Analysis Cuvette

Spectrophotometer and associated sample vials and reagents

Peristaltic Pump

0.45-micron Large Capacity Filter Cartridges

Silicone Tubing
Polyethylene Tubing
Distilled Water
Deionized Water
Spray Water Bottles
1% Liquinox Solution
Sample Cup or Beaker

Calibration Standards for Each Meter

Miscellaneous Field Tools:

Socket for Flush Mounted Wells

Cutting Shears

Spare Combination Locks Christie Box Opening Tool Flat Head Screwdriver

Extra Batteries Nitrile Gloves

Documentation: Daily Field Record (DFR)

Water Level Monitoring Record (attached)
Well Development Record (attached)
Well Sampling Record (attached)

Micro-Purge Sampling Record (attached)

Boring Grab Groundwater Sampling Record (attached)

General Water Sampling Record (attached)

Multi Parameter Meter Calibration Sheet (attached)

Single Point Calibration Sheet (attached)



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This Standard Operating Procedure (SOP) describes the general methodology for water level measurement from wells and measuring field parameters in water. Field parameters typically consist of pH, specific electrical conductance (SEC), turbidity, oxidation-reduction potential (ORP), temperature, and dissolved oxygen (DO). Alkalinity, dissolved zinc, and sulfate may also be measured in the field. Refer to the manufacturer's recommendations for specific operational procedures and calibration requirements for each type of field instrumentation and field analytical method described in this SOP.

All field measurements of water will be performed by appropriately trained field staff under the guidance of a California-licensed Professional Geologist or Professional Engineer.

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and associated work plans.

3.1 SET-UP AND EQUIPMENT CALIBRATION

Prior to taking any field measurements, sampling personnel will assemble all necessary equipment and calibration standards. All instruments to be used will be checked and calibrated per the manufacturer's instructions and as often as recommended by the manufacturer to ensure they are in proper working condition. Calibration data including the concentration of the calibration standard(s) and the calibration reading for the check standard(s) will be recorded on a Multi Parameter Meter Calibration Sheet, and/or a Single Point Calibration Sheet, as applicable (attached).

3.2 WATER LEVEL MEASUREMENT

Water levels may be measured in monitoring wells, piezometers, and water supply wells or in other types of structures where water can accumulate (e.g. mine shafts). For ease of use, "well" will refer to any structure in which the water level is being measured. Open the well by removing the lid on the well box and remove the well cap. When opening the well box and removing the cap, be sure to keep your head away from the top of the open casing to avoid inhaling any fumes that may reside within the well.

Decontaminate all water level measurement equipment as described in SOP 4.0 – Equipment Decontamination prior to inserting any instruments into the well.

Water level measurements will be referenced to a known elevation datum. The measuring point at the top of the well casing (generally the north side of the casing) or some other permanent



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reference point will be permanently marked and surveyed. Measurements will be consistently taken from the same marked point. Water levels will be measured with an electrical sounding device, a hydrocarbon interface measuring device, or equivalent device.

The static water level will be measured in each well using an electronic water level indicator. Measurements will be made by recording the depth-to-water (DTW) and repeating the measurement until at least two consecutive depth readings within 0.01-foot are measured. The final water level measurement for each well will be recorded in the field on a Water Level Monitoring Record.

When attempting to collect a DTW measurement, if a vacuum or a pressure buildup is detected upon opening the airtight well cap, an initial depth to water level will be obtained and the well will be allowed to equilibrate for approximately 3-5 minutes. After the field geologist or engineer has used professional judgment to determine that the water table is stable, another DTW measurement within the well will be obtained. Additional measurements will be obtained at 3-5 minute intervals until at least two consecutive depth readings are within 0.01-foot.

The field geologist or engineer may also measure the depth-to-bottom (DTB), or the depth to the bottom of the well by lowering a measuring device (e.g., sounding device) to the bottom of the well. If the sounding device has a "zero measuring point" at a place other than the tip of the probe, the difference in measurement will be added or subtracted from the reading so that the recorded value is an accurate measurement from top of casing to DTB.

At the completion of the DTW and possible DTB measurements, the field geologist or engineer will wipe down the down-hole equipment with a new paper towel to remove excess water or debris from the tool and decontaminate as appropriate.

3.3 FIELD PARAMETERS

Generally, a multi-parameter water quality meter (YSI is the brand that is commonly used) will be used to measure field parameters. The following describes measuring field parameters of pH, SEC or EC, temperature, turbidity, ORP, and DO using an YSI meter or similar equipment.

1.8.8 Ha

The general procedures for the operation, calibration, and maintenance of the field pH meter and its accessories are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements



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and user recommendations. Manufacturer's specifications and recommendations should be followed when using the pH meter.

Prior to use each day, the pH meter should be examined for cleanliness, for defects, and for any possible need of repair. The examination should include the battery and electrode. Once the pH meter is observed to be in correct operating condition, it should be calibrated using a minimum of a three-point calibration using 4.0, 7.0, and 10.0 pH standard solutions (purchased from a reputable vendor, and non-expired). Prior to beginning the calibration, the expiration date for each of the calibration standards will be checked. Standard solutions that have expired will not be used and will be properly disposed in accordance with SOP 5.0 -- IDW Disposal. A record of the pH reading for each concentration of standard and any calibration notes will be denoted on the Multi Parameter Meter Calibration Sheet.

3.3.2 Specific Electrical Conductance

The general operation, calibration, and maintenance for use of the SEC meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations.

Manufacturer's specifications and recommendations should be followed when using the conductivity meter.

Prior to use each day, the SEC meter should be examined for cleanliness, for defects, and for possible need of repair. The examination should include the battery and the probe. Once the conductivity meter is observed to be in correct operating condition, it should be calibrated using a minimum standard solution of 1,000 micro-Siemens (μ S/cm) at 25 degrees Celsius (° C) (purchased from a reputable vendor). Prior to beginning the calibration, the expiration date for the calibration standard will be checked. Standard solutions that have expired will not be used and will be properly disposed of in accordance with SOP 5.0 – IDW Disposal. A record of SEC reading and any calibration notes will be denoted on the Multi Parameter Meter Calibration Sheet.

3.3.3 Temperature

The operation procedure of the thermometer or temperature probe for use in the field is included in the instruction manual provided with the equipment. Prior to use each day, examine the thermometer/probe for cleanliness, defects, and any possible need of repair. Temperature calibration is done by the manufacturer.



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3.3.4 Turbidity

The general procedures for the operation, calibration, and maintenance of a field turbidity meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations. Turbidity meters used can either be part of a multi-parameter unit or a single turbidity meter (La Motte is the brand commonly used).

Prior to use each day, the turbidity meter should be examined for cleanliness, for defects, and for possible need of repair. The examination should include the battery. Once the turbidity meter is observed to be in correct operating condition, it should be blanked with a 0.0 NTU standard solution then calibrated using a standard solution close to the expected sample range (purchased from a reputable vendor). Prior to beginning the calibration, the expiration date for each of the calibration standards will be checked. Standard solutions that have expired will not be used and will be properly disposed in accordance with SOP 5.0 – IDW Disposal. Acceptance limits for each standard and any calibration notes will be denoted on the Multi Parameter Meter Calibration Sheet.

If the turbidity meter reads in AU instead of NTU, then the sample is too turbid to collect a measurement. For documentation purposes, it should be noted that the meter is reading >500 NTU instead of noting the value in AU.

3.3.5 Oxidation-Reduction Potential

The general procedures for the operation, calibration, and maintenance of the field ORP are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations.

Prior to use, examine the ORP meter for cleanliness, defects, and any possible need of repair. The examination should include the battery and probe. Once the ORP meter is observed to be in correct operating condition, it should be calibrated using a minimum standard solution of 100 milliVolts (mV) (purchased from a reputable vendor). Prior to beginning the calibration, the expiration date for the calibration standard will be checked. Standard solutions that have expired will not be used and will be properly disposed of in accordance with SOP 5.0 – IDW Disposal. A record of the ORP reading and all calibration notes will be denoted on the Multi Parameter Meter Calibration Sheet.



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3.3.6 Dissolved Oxygen

The general procedures for the operation, calibration, and maintenance of a field DO meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations.

Prior to use, examine the DO meter for cleanliness, defects, and any possible need of repair. The examination should include the battery and probe. Once the DO meter is observed to be in correct operating condition, it should be calibrated using distilled water and the barometric pressure of the atmosphere where the DO is being collected. All calibration notes must be recorded on the Multi Parameter Meter Calibration Sheet.

Dissolved Oxygen is generally calibrated in percent (%) but the sample readings *MUST* be recorded in mg/L. Dissolved Oxygen levels vary based by temperature, barometric pressure, and salinity. The general saturation levels range from 8 to 14 mg/L DO. If the meter reads above the saturation level for the current temperature and pressure, it should be recalibrated. If it is still out of range, the membrane and solution should be changed.

3.3.7 Rhodamine

A field fluorometer will be used to measure rhodamine dye concentrations during pilot test tracer studies. The operation procedure for the fluorometer for use in the field is included in the instruction manual provided with the equipment. Prior to use each day, examine the fluorometer for cleanliness, defects, and any possible need of repair. The examination should include the battery and probe.

Once the fluorometer is observed to be in correct operating condition, it should be calibrated using a primary standard made from the rhodamine dye used for the tracer study. The primary standard shall be prepared using the Pond 11 discharge water diluted to approximate the anticipated rock drain inlet tracer concentration. A record of the fluorometer reading and all calibration notes shall be denoted on the Single Point Calibration Sheet.

3.3.8 Tagout

If any of the above water quality meters are found to be above or below the range of concentration for check standard, the equipment must be locked out and tagged out so it will not



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be used inadvertently. A replacement meter shall be obtained and properly calibrated while the out of range equipment is repaired.

3.3.9 Procedures for Testing a Sample

Samples will be tested for the above water quality parameters by triple rinsing a small container with the sample water before filling the container with the sample to be tested. Once the container is filled to the level in which all the appropriate probes will be submerged the probe shall be inserted into the container and the parameters shall be allowed to stabilize. If more than one meter is used then a second container shall be filled in order to submerge the second probe.

In some cases a flow through cell may be used while collecting water quality parameters. If a flow-through cell is used it must be decontaminated in between each sample location (see SOP 4.0 – Equipment Decontamination). Do not use detergents when decontaminating probes. Only rinse probes with fresh or distilled water.

Once the water quality readings have stabilized, but before the temperature of the sample begins to change (less than 5 degrees Celsius difference from the initial temperature reading) because of the ambient temperature, the values for each parameter will be recorded on the appropriate sampling record (attached).

3.4 FIELD ANALYTICAL METHODS FOR ALKALINITY, ZINC, AND SULFATE

Field measurement of alkalinity, zinc, and sulfate will be made with a HACH[®] DR 3900TM Spectrophotometer, YSI 9300 Spectrophotometer, or comparable field instrument. The appropriate reagents and methods shall be employed for use with the specific field instrument.

Field measurement of alkalinity, zinc, and sulfate will be made with a (or similar) using Total Alkalinity),), and) respectively. Prior to use each day, the spectrophotometer should be examined for cleanliness, for defects, and for any possible need of repair. The examination should include the battery.

For the HACH® DR 3900 Spectrophotometer, the following methods and reagent sets will be used:

- Total Alkalinity: TNT870 Reagent Set, HACH[®] Method 10239
- Dissolved Zinc: Zinc Reagent Set, HACH[®] Method 8009

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Sulfate: Sulfa Ver 4[®] Powder Pillows or AccuVac[®] Ampuls, HACH[®] Method 8051

For the YSI 9300 Spectrophotometer, the following methods and reagent sets will be used:

- Total Alkalinity: YPM188 or YAP188 reagent kit; YSI Method YSIP2
- Dissolved Zinc: YPM148 or YAP148 reagent kit; YSI Method YSIP35
- Sulfate: YPM154 or YAP154 reagent kit; YSI Method YSIP32

Prior to use each day, the spectrophotometer should be examined for cleanliness, for defects, and for any possible need of repair. The examination should include the battery.

The following sections describe methods for analysis of total alkalinity, zinc, and sulfate using the HACH® DR 3900 Spectrophotometer. Spectrophotometers not manufactured by YSI should be operated and calibrated according to the manufacturer's instructions. For analysis of other constituents not described here, the appropriate methodology as developed by the manufacturer for the specific instrument shall be used.

3.4.1 TOTAL ALKALINITY

3.4.1.1 ANALYSIS

To measure total alkalinity, the sample will be field filtered prior to analysis to remove particles. A pipet will be used to place 2 ml aliquot of the Total Alkalinity TNT870 Reagent solution into the glass sample vial. Add 0.5 mL of sample water into the vial. The container will be inverted several times and allowed to react for five minutes using a timer. At the conclusion of five minutes, wipe off the glass sample cell with a soft clean cloth to remove finger prints or smudges which can interfere with sample reading. The instrument reads the barcode on the test vial to select the method and makes the measurements. The results are reported in mg/L of calcium carbonate (CaCO₃).

If the result is reported as 400 mg/L of $CaCO_3$ or higher, the sample is at or above the upper limit and a dilution of the sample must be performed (see Section 3.4.4 for instructions on how to dilute a sample). If the result of an un-diluted sample is reported as 25 mg/L $CaCO_3$, the sample is at or below the lower limit and should be reported as 25 mg/L.

3.4.1.2 CALIBRATION/ACCURACY CHECK

According to YSI, the colorimeter is pre-calibrated for the total alkalinity measurement; however, at a minimum, an accuracy check should be performed at least once a week. To run an

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accuracy check, a 1.0 mg/L iron solution will be used. It can be purchased at the 1.0 mg/L concentration or it can be diluted from a more concentrated stock solution.

If no dilution is necessary, the analysis procedure described in Section D6.4.1.1 will be used to test the accuracy of the instrument. Results should be between 0.9 mg/L and 1.1 mg/L Fe. All accuracy check results must be recorded on a HACH Accuracy Check Sheet.

If using a dilution to prepare the 1.0 mg/L total dissolved iron standard solution from a concentrated stock solution (example here is a 100 mg/L concentration stock solution, but other concentrations may be used as well, with appropriate dilution ratios):

- Wash a 100 mL volumetric flask with a 1% Liquinox solution. Rinse with copious amounts of deionized or distilled water (until no more bubbles are visible with agitation).
- Fill flask about halfway with deionized water.
- Using a graduated pipette, measure 1.0 mL of the purchased 100 mg/L Fe solution and add it to the clean volumetric flask.
- Carefully, bring the 100 mL graduated cylinder to volume with deionized or distilled water, cap securely and invert several times.

The solution will need to be prepared each time an accuracy check is run.

Once the solution has been prepared, the analysis procedure described in Section D6.4.1.1 will be used to test the accuracy of the instrument. Results should be between 0.9 mg/L and 1.1 mg/L Fe. All accuracy check results must be recorded on a HACH® Accuracy Check Sheet.

3.4.2 ZINC

3.4.2.1 ANALYSIS

To measure total alkalinity, the sample will be field filtered prior to analysis to remove particles. To analyze the sample, select stored Program 780, when using the HACH® Benchtop Spectrophotometer (or other similar program depending on the instrument manufacturer). Select program by pressing the "prgm" button, followed by "780". A 25-ml graduated mixing cylinder will be filled with a 20 mL sample aliquot. Add the contents of one ZincoVer® 5 Reagent Powder Pillow to the mixing cylinder. Add a stopper to the top mixing cylinder and invert several



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times to dissolve the powder completely. The sample should be orange. If the sample is not orange (brown or blue), the zinc concentration is too high or an interfering metal is present and the sample will have to be diluted and retested (see below). If the sample does not need to be diluted, prepare a blank by pouring 10 mL of solution from the mixing cylinder into a sample cell. Then using a plastic dropper, add 0.5 mL of cyclohexanaone to the remaining solution in the mixing cylinder. Start the 30-second instrument timer to allow for the reaction to take place. During this reaction period, place the stopper onto the mixing cylinder and vigorously shake the prepared sample and start the 30-second instrument timer. The sample will be reddish-orange, brown, or blue depending on the zinc concentration. Following this reaction period, an addition three-minute reaction period will begin. Once the timer expires, pour the prepared sample solution from the mixing cylinder into a second sample cell. When the timer expires, wipe the blank sample cell with a soft clean cloth to remove finger prints or smudges which can interfere with the meter reading, insert it into the spectrophotomer, and press "zero" to zero the meter. Wipe the prepared sample cell with a soft clean cloth to remove finger prints or smudges, insert it into the spectrophotomer, and press "read" and record the results mg/L of Zn.

If the result is reported as 3.0 mg/L or higher, the sample is at or above the upper limit and a dilution of the sample must be performed (see Section 3.4.4 for instructions on how to dilute a sample). If the result of an un-diluted sample is reported as 0.01 mg/L, the sample is at or below the lower limit and should be reported as <0.01 mg/L.

3.4.3 **SULFATE** (SO₄²⁻)

3.4.3.1 ANALYSIS

To measure sulfate, the sample will be filtered prior to analysis. The glass sample vial will first be rinsed with the sample and emptied. To analyze the sample, select stored Program 680, if using SulfaVer® 4 powder pillows, or Program 685, if using SulfaVer® 4 AccuVac® Ampuls, when using the HACH® DR 3900 Spectrophotometer (or other similar program depending on the instrument manufacturer). Select program by pressing the "prgm" button, followed by "680" (if using pillow packets) or "685" (if using AccuVac® Ampuls). A 10 ml aliquot will be transferred to the 10 mL mark in two separate glass sample cells. If a dilution is required, then both of the rinsed HACH® sample cells should be filled to the 10 mL line with diluted sample (see section 3.4.4 for instructions on how to dilute a sample). Wipe off one of the glass sample cells with a soft clean cloth to remove finger prints or smudges which can interfere with the meter reading, insert it into the colorimeter, and press "zero" to zero the meter. Add the contents of one SulfaVer® 4 powder pillow to the second sample cell and secure the cap. The container will be inverted several times and allowed to react for five minutes using a timer. At the conclusion of



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five minutes, wipe off the glass sample cell with a soft clean cloth to remove finger prints or smudges which can interfere with sample reading. Insert the sample into the spectrophotometer and press "read" and record the result.

If the result is reported as 70 mg/L of $SO_4^{2^-}$ or higher, the sample is at or above the upper limit and a dilution of the sample must be performed (see Section 3.4.4 for instructions on how to dilute a sample). If the result of an un-diluted sample is reported as 2 mg/L, the sample is at or below the lower limit and should be reported as <2 mg/L. If using the SulfaVer® 4 AccuVac® Ampuls, follow the procedures included in the instruction manual provided with the equipment. Ampoules

3.4.3.2 CALIBRATION/ACCURACY CHECK

For sulfate, a new calibration conducted by the user is recommended for each new lot of reagent; however the Standard Adjust feature is typically sufficient for field purposes.

We will perform the Accuracy Check Standard Solution Method. Use a 50 mg/L sulfate standard if available. Otherwise, prepare a 50mg/L standard solution using the following procedure:

- Wash a 100 mL volumetric flask with a 1% Liquinox solution. Rinse with copious amounts of deionized or distilled water (until no more bubbles are visible with agitation).
- Fill flask about halfway with deionized water.
- Using a graduated pipette, transfer 1.0mL of a PourRite Ampoule Standard for Sulfate (2500mg/L) to the 50mL volumetric flask (you can also transfer 2.0mL into a 100mL volumetric flask if one is available).
- Carefully bring the volume in the flask up to the line by adding deionized water. Place cap on flask and slowly invert 3 times.
- Run this solution as a sample in the method described above.

According to HACH[®], a standard adjust is recommended when using the stored programs 680 or 685. To adjust the calibration curve using the reading obtained with the 50-mg/L standard solution, run the standard as a sample as described above, press the "setup" key and scroll to the STD setup option. Press "enter" to activate the standard adjust option. Then enter "50" to



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edit the standard concentration to match that of the standard used. Press "enter" to complete the adjustment.

Refer to instrument calibration instructions for all other instrument manufacturers. If a new calibration is performed using the HACH® spectrophotometer then an accuracy check is not required. All calibration results must be recorded on the HACH® Accuracy Check Sheet.

3.4.4 SAMPLE DILUTION

Each analysis has an upper concentration limit which is listed in the manufacturer's instructions. If the initial sample reading is greater than the upper concentration limit, a dilution of the sample will be completed. A dilution of 1 part sample to 99 parts deionized water for a total of 100 parts (1:100) will be conducted first. If the resulting value is less than half the detection limit, a dilution of 1 part sample to 49 parts deionized water for a total of 50 parts (1:50) will be conducted. Fill both sample cells to the desired level with the diluted sample. Wipe off one of the glass sample cells with a soft clean cloth to remove finger prints or smudges which can interfere with the meter reading, insert it into the colorimeter, and press "zero" to zero the meter. After the meter has been zeroed, run the test following the desired analysis procedures as outlined above. The resultant value will be multiplied by 100 or 50, based on the respective dilution completed to determine an actual concentration. Record *only* the final dilution results on the Sampling Record. Write all the dilution ratios that were made on the DFR, but not the out of range results because they are not accurate and might accidently get mixed up with a correct value.



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3.5 REVISION LOG

Revision Number	Author	Description of Change (Section number)	Date



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ATTACHMENTS

- Water Level Monitoring Record
- Well Sampling Record
- Grab Groundwater Sampling Record
- Multi Parameter Calibration Sheet
- Single Point Calibration Sheet

WATER LEVEL MONITORING RECORD



Project Na	me:			Project and Task Number	er:			
Date: Measured b								
				eviations may be used.				
				D = Dedicated Pump				
ST = Stee	el Tape	ES = Electric	Sounder	MP = Measuring Point	DTW = Depth to Water			
Assumed	Dry = DTW	Measuremer	nt Below Est	imated Bottom of Screen	DTB = Depth to Bottom			
Well No.	ell No. Time Water Level Below MP (feet) Depth to Bottom Below MP (feet)*			Remarks				

*When using a Solinst WL Meter, add 0.3' to measurement to account for the "zero measurir of the probe	ng point" in the	middle
	Dana	£
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WELL SAMPLING RECORD



Well ID:							Initial Depth to Water:					
Sample ID							Total Depth of Well:					
Sample Da	ate:	Sar	mple Time:			We	Well Diameter:					
Sample Depth:								ume Cal				
Project an	d Task No).:				To Hia	ital Depth meter ca	n of Well ising) or (– Initial 1 652 (i	Deptl f 4" di	h to W amete	(ater) x 0.163 (if 2"
Project Na	ame:							•	,			.
						Ca _	lculation	1:				
Purged By	/ :					10	asing V	olume: _				
Method of	Purging:		Sampling	g:		_ 3 C	asing V	olumes:				
Pump Typ	e (& disch	arge line)	:									
						To:	tal Gallo	ns Remo	oved: _			
Time					SpC S/cm)	DO (mg/L)	ORP (mV)	Turbi (NT			Remarks blor, odor, sediment, prox. purge rate, etc.)	
HACH Res	sults (mg/L	_) Dilu	tion Factor	Final Re	sult:	(multip	ly by 100	for 1:10	0 dilutio	n or 5	50 for 1	1:50 dilution, etc.)
				QA/QC S	ampli					1	ı	
(duplicate, r	C Type rinsate blank blank)	.,	QA/QC Sam (GWLMMDD			QA/Q Samp Time	le In	ACH QA itial Res (mg/L)	ults		ition etor	Final Result (mg/L)
N. d.												
Notes:												
	Instrument(s) Used (model or unit no.):											
Samplers Name:						Samplers Signature:						

WELL SAMPLING RECORD



					3 (Casing Volumes:				
Time	Depth to Water (feet btoc)	Cum. Vol. (gal.)	pH (units)	Temp. (°C)	SpC (μS/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Remarks (color, odor, sediment, approx. purge rate, etc.)	
Notes:										
140162.										

GENERAL WATER SAMPLING RECORD



Location ID	:	_				Loca	tion Type:				
Sample ID:					Project and Task No.:						
Sample Date	e:	Sample Tir			Project Name:						
Method of Sampling:						Samı	oled By:				
Time	pH (units)	Temp. (°C)		SpC S/cm)	DO (mg/L)	ORP (mV)			Remarks (color and sediment)		
HACH Resu	lts (mg/L)	Dilution Fac	tor		Limit (E	L) for				1:50 dilution, etc.) ulfate is 2 ; record	
Alkalinity:											
Zinc:											
Sulfate:											
				QA/QC Sa	mpling	& QA	/QC HACH				
QA/QC (duplicate, ri	nsate or	QA/QC S				nple			Dilution Factor	Final Result (mg/L)	
							Alkalinity:				
							Zinc:				
							Sulfate:				
Notes:											
Duplicate C	allactad?			Duplicat	la Samn	lo ID:			Sampl	e Time:	
Equip Rinsa		ollected?		Rinsate	<u>_</u>					e Time:	
						J.					
. ioia biailk	Field Blank Collected? Field Blank ID: Sample Time:										
Samplers Name:				San	Samplers Signature:						



	MULTI PARAMETER MET	TER CALIBRATION SHEET	
Project Name:		Date:	
Task Name:		Project Number:	
Equipment Type: Mu	ılti Parameter		
Manufacturer:		Owner of Meter:	
Model Number:		Serial Number:	
Date of Last Calibra	ation:		
*Be	sure to calibrate in the order li	isted	
Calibration #1: Specifi	ic Conductance (SEC; No tempe	rature adjust) Time:	
Calibration Standa	rd:		
Instrument Reading	g:		
Calibration #2: pH 7 (a	adjust for temperature)	Time:	_
Calibration Standa	rd:		
Instrument Reading	g:		
Calibration #3: pH 4 (a	adjust for temperature)	Time:	
Calibration Standa	rd:		
Instrument Reading	g:		
Calibration #4: pH 10	(adjust for temperature)	Time:	
Calibration Standa	rd:		
Instrument Reading	g:	<u> </u>	
Calibration #5: ORP (adjust for temperature)	Time:	
Calibration Standa	rd:		
Instrument Reading	g:	<u> </u>	
Calibration #6: DO %		Time:	
Calibration Standa	rd:		
Instrument Reading	g:	Barometric Pressure:	
Misc. Comments:			
		Calibrated by:	



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4.0 - EQUIPMENT DECONTAMINATION

Purpose and Scope: The purpose of this document is to describe procedures for equipment

decontamination. It describes decontamination methods and provides

specific procedures for decontaminating drilling and excavation equipment, submersible pumps, decontamination for the collection of

equipment blanks, and water level meters.

Equipment: Steam Cleaner

Four 5-gallon buckets with lids

Bucket labels

Brushes

Distilled water Potable water Spray bottles Paper towels

Liquinox® or other Non-Phosphate Cleaning Solution (not Alconox®)

10 mil visqueen

Documentation: Daily Field Record (DFR)

Atlantic Richfield Chain-of-Custody (COC) Form

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and Analysis Plan (SAP) and applicable work plans.

4.1 DECONTAMINATION PROCEDURES

Decontamination procedures described in this section are applicable to non-dedicated, non-disposable sampling equipment. The following subsections describe the methods of decontamination and procedures for decontaminating specific types of sampling equipment.

4.1.1 Decontamination Methods

All sampling equipment must be decontaminated after it arrives onto the site and before each sampling operation. <u>This includes subcontractor equipment</u>. Decontamination onsite will use one of the methods below:

- Three-Step System
- Steam Cleaner

The procedures for decontamination using the three-step system or steam cleaner are described in the following subsections. The exception to using the three-step system or a



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steam cleaner for decontamination is when cleaning a water level meter. This is described in Section 4.1.2.4 of this SOP.

4.1.1.1 Three Step System

The three step decontamination system consists of washing the sampling equipment: (1) in soapy water using a non-phosphate (Liquinox®) solution, (2) rinsing with potable water and (3) rinsing again with distilled water. The Liquinox® solution will be mixed in accordance with the manufacturer's recommendations. Equipment will be washed in a row of three containers. Depending on the equipment to be decontaminated, spray bottles containing the applicable solutions may be used. Hard bristle bottle brushes may be used to remove mud and debris prior to the three step system with an optional fourth container. Sample equipment should be allowed to drain dry after the final distilled water rise. Decontamination water will be disposed of according to procedures described in SOP 5.0 – Investigation Derived Waste Disposal.

4.1.1.2 Steam Cleaner

The steam cleaner will be supplied by a subcontractor and operated according to the manufacturer's recommendations. It will be capable of generating a working pressure of approximately 1,500 to 2,000 pounds per square inch (psi), a discharge rate of 3 to 5 gallons per minute (gpm), and an operating temperature of approximately 130 to 150 degrees Fahrenheit (°F).

The steam cleaner will be used within a decontamination station designed to capture all of the water. The decontamination station may be mounted on a portable trailer or constructed onsite and will be supplied or built by a subcontractor. If constructed, the on-site decontamination area will be lined and bermed with two layers of 10 mil visqueen to contain rinsate from steam cleaning operations. If appropriate, the decontamination area will be designed to allow heavy equipment (backhoe, drilling rig, and support vehicles) to drive onto the visqueen. During operation of the steam cleaner, the field engineer or geologist will establish and maintain an exclusion zone. Decontamination water will be retained and disposed according to procedures described in SOP 5.0 – Investigation Derived Waste Disposal.

4.1.2 Sampling Equipment

The following subsections provide specific details for decontaminating drilling and excavation equipment, submersible pumps, equipment blanks, and water level meters.



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4.1.2.1 Drilling and Excavation Equipment

Drilling and excavating equipment, including backhoe buckets, drill bits, casing, augers, and tools or other equipment that have come in contact with potentially impacted soils or water will be cleaned between each location, as appropriate. After completion of each boring, drill casing or augers, drill bits and drill rods will be transported by truck to the steam cleaning area. Drill casing from the monitoring well drilling procedures will be lifted from the support truck and cleaned within the decontamination station. Heavy tooling with edges that can damage the decontamination area will be placed on lumber in the decontamination area for cleaning. Rinsate collected in the decontamination area will be retained and disposed according to SOP 5.0 – Investigation Derived Waste Disposal.

4.1.2.2 Submersible and Bladder Pumps

If a non-dedicated submersible pump is used, it will be cleaned prior to use and between sampling locations using the three-step system. First, the pump intake device will be submersed into non-phosphate cleaning solution (Liquinox®) and recycled within a bucket for at least 30 seconds. Second, the pump will be submersed into a bucket containing potable water and recycled within the container for at least 30 seconds. The second step should be performed sufficiently rinse the suds from the pump. The third step involves rinsing the pump within a bucket filled with distilled water using the same method as Steps 1 and 2.

If a non-dedicated bladder pump is used, it will first be disassembled and decontaminated using the three-step system. If so equipped, the disposable bladder will be removed and replaced with a new bladder. The used bladder will be disposed using project procedures for disposing solid waste. Then, the bladder pump will be assembled and rinsed with distilled water.

4.1.2.3 Equipment Blanks

As appropriate, equipment blanks will be collected after decontamination of the sampling equipment during sampling activities to provide an additional check on possible sources of contamination related to field sampling instruments. Sampling equipment (e.g., the shoe from a core sampler, hand auger, shovel, drive-sampler, etc.) will be decontaminated using the three-step system.

4.1.2.4 Water Level Meters

Water level meters will be decontaminated using a two-step system. This system consists of a spray bottle containing non-phosphate detergent (Liquinox®) mixed with water and a spray



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bottle containing distilled water. The Liquinox[®] solution will be mixed in accordance with the manufacturer's recommendations. The soapy water will be sprayed on the portion of the water level meter that was submerged and then rinsed by spraying distilled water until all suds are removed. The submerged portion of the water level meter will then be wiped down with a paper towel. If residual dirt or other contaminants remain on the water level meter after being rinsed, the above steps will be repeated using a brush to remove the remaining debris. Rinse water from the above procedures will be captured in a bucket or other appropriate container, labeled, and disposed in accordance with procedures described in SOP 5.0 – Investigation Derived Waste Disposal.



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4.2 REVISION LOG

Revision Number	Author	Description of Change (Section number)	Date



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5.0 - INVESTIGATION DERIVED WASTE DISPOSAL

Purpose and Scope: The purpose of this document is to present procedures for containment

and disposal of investigation derived waste such as soil, water, and

materials.

Equipment: Buckets, containers with covers for soil and water

(e.g., 55-gallon drums, 20-yard roll-off bins, Baker Tanks™)

Waste disposal labels

Appropriate sample containers and sampling equipment

Miscellaneous tools Safety Equipment

Documentation: Daily Field Record (DFR)

Waste Tracking Log (attached)

Maps/plot plan

Camera

This Standard Operating Procedure (SOP) is to be used in conjunction with the Sampling and analysis Plan (SAP) and applicable work plans.

The procedures below are to be followed for investigation derived waste consisting of water, soil, or materials such as personal protective equipment (PPE) or disposable sampling equipment. Investigation derived groundwater will be generated from well development and purging activities. Investigation derived waste water will be generated during decontamination activities. Investigation derived soil will be generated from soil borings.

All containers containing waste will be kept closed and sealed at all times unless actively adding waste. Each container must have a visible and legible label present. Labels will be constructed of weather-resistant vinyl and waterproof ink markers will be used to add information in the field. All empty containers must have a label that indicates that the container is empty. Prior to filling any waste containers, the sampler will replace the empty label with a label that describes the source of the waste (well or boring ID), the contents (soil or water), date accumulation started, date accumulation finished, and a name and contact information of the generator. The location of the waste generated will be documented on a waste tracking log (attached).

5.1 WATER DISPOSAL PROCEDURES

Groundwater produced during the well development and purging activities will be discharged to the ground surface near the well for evaporation and infiltration. Water will be discharged in a manner that prevents erosion, pooling of water, or migration to a surface water body and will be



Standard Operating Procedures Investigation Derived Waste Disposal

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performed in accordance with the HSSE Program document and the TSHASP. Measures to prevent erosion or migration may consist of installing silt fencing down slope of discharge areas or transporting and land applying water in a more appropriate location. If surface discharge is not practicable or allowed, water may be containerized (e.g. in a pipe, hose, or drum) and transported to an onsite treatment system, or may be transported off-site for appropriate disposal.

Waste water produced from decontamination activities will be disposed in the same manner as described above. This includes Liquinox® (a non-phosphate detergent) that is mixed with water using the manufacturer's recommendations. Alconox® or other detergents containing phosphates will not be used on site. If other cleaning agents are used during decontamination, the field engineer or geologist will contact the Project Manager for guidance on the proper disposal procedure.

It is not anticipated that investigation-derived waste water will be transported off site.

5.2 SOIL DISPOSAL PROCEDURES

It is anticipated that most soil investigations will be performed in areas that have unconsolidated material at the surface that was left behind from previous site activities (i.e., mining, construction, landslides). Any soil or mud developed during the drilling or excavation activities are expected to have similar characteristics as the disturbed material that exists in the vicinity of the investigation. Therefore, if disturbed material already exists at the surface, any soil or mud developed during the investigation will be spread evenly in the immediate vicinity. The material will be spread in a manner that has a low profile as to prevent windblown dust from occurring. These soil disposal activities will be performed in a manner that prevents migration to a surface water body and in accordance with the HSSE Program document and the TSHASP.

If soil and mud produced during the investigation is suspected to contain other contaminants (e.g., petroleum odors, ethanol odor), the field Engineer or Geologist will contact the Project Manager for guidance. Exceptions to the above soil disposal procedures will be addressed on a case-by-case basis.

5.3 MATERIAL DISPOSAL PROCEDURES

Used PPE will be disposed in containers that are sealed and labeled. These containers will be stored onsite and later transported to an appropriate offsite disposal facility.



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Used sampling devices that have come in contact with low pH water (e.g., bailers, sample bottles) will be rinsed, cut in half, and then placed in the onsite municipal solid waste trash receptacle. The sampling devices will be rinsed with neutral pH water and the rinse water will be disposed of as specified in Section 5.1.

All other disposable equipment, including items such as rope and non-hazardous well construction materials will be disposed in the onsite municipal solid waste trash receptacle. The exception is for the disposal of equipment that has come in contact with contaminants that are suspected to be non-native to the area or those that are known to be hazardous (e.g., ethanol, diesel fuel, etc.). If this situation exists, the field engineer or geologist will contact the Project Manager for guidance.

5.4 OFFSITE FACILITY DISPOSAL PROCEDURES

Offsite disposal of investigation derived waste is not expected. However in the event that it is needed, the location and quantity of the waste that is generated will be documented on a map and Waste Tracking Log (attached).

Offsite disposal of waste will be performed in accordance with appropriate Federal, State, and local regulations. A sample of the waste to be disposed at an offsite facility will be collected and submitted to a laboratory for analysis. Analytical results of the sample will then be sent to the disposal facility where a waste profile will be generated. The profile will be reviewed and signed by a designated Atlantic Richfield representative. The U.S. EPA will then be notified of all types and quantities of waste prior to its shipment off site.

Upon approval of the waste profile, an appropriate manifest (Hazardous or Non-Hazardous) will be completed. All waste manifests will be reviewed and signed by a designated Atlantic Richfield representative. The truck driver transporting the waste will also sign and keep the manifest in his presence at all times while transporting the container to the disposal facility. The truck driver will be responsible for adhering to all Department of Transport (DOT) rules and regulations for the transport of waste on public roads.



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5.5 REVISION LOG

Revision Number	Author	Description of Change (Section number)	Date



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ATTACHMENT

Waste Tracking Log

Waste Tracking Log

Rico-Argentine Mine Site - Rico Tunnels Operable Unit OU01 Rico, Colorado



Date	Waste Type and Volume	Source Location	Container Type and Volume	Number of Containers	Storage Location

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Page	of	

Waste Tracking Log

Rico-Argentine Mine Site - Rico Tunnels Operable Unit OU01 Rico, Colorado



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6.0 - STREAM FLOW MEASUREMENT AND SURFACE WATER SAMPLING

Purpose and Scope: The purpose of this document is to provide a general outline for

developing site specific procedures for collection of representative surface water samples measurements in small streams, small rivers or

ponds and lakes.

Equipment: Surface Water Sample Collection Devices:

Dip sampler;

Discrete depth sampler and associated equipment;

Peristaltic pump, power supply and associated equipment;

Directional Compass;

25-foot Steel Tape and 100-foot Flexible Tape Measure:

Survey stakes, flagging, hammer;

Marking Buoys, pre-stretched line and anchors; Boat or Raft (deep River or Pond/Lake Sampling);

Appropriate Line;

USCG Approved Type III Life Vests;

Vertical Staff Gauge;

3-inch, schedule 40 PVC Pipe, length to be determined

Electronic Depth Gauge;

Volumetric Flow Measuring Structure (Weir)

V-Notch Flume

Sample containers (cleaned and provided by the laboratory);

Ice chests and blue or double bagged ice;

Tarps;

Miscellaneous tools; Safety Equipment,

Hand-Held Global Positioning System (GPS) device; and

Hip Boots and Knee-high water tight boots.



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Documentation: Daily Field Record (DFR);

Maps;

Digital Camera and Photo Log;

Sample Control Log;

Atlantic Richfield Chain-of-Custody (COC) form or laboratory equivalent;

YSI Calibration Sheet (or other means to document instrument

calibration);

Turbidity Calibration Sheet;

General Water Sampling Form; and

Stream Flow (Discharge) Measurement Form (attached).

This SOP is to be used in conjunction with the Sampling and Analysis Plan (SAP) and applicable work plans.

6.1 STREAM FLOW MEASUREMENT

Small stream and river volumetric flow can be calculated with measurements of the stream cross-sectional area and the velocity of flow through that area using the following formula.

 $Q = V \times A$

Where,

Q = Discharge (in cubic feet per second)

V = Velocity (in feet per second)

A = Area (in square feet)

The area of the cross-section through which water is flowing will be determined by one or more techniques based on the overall general size of the stream (width and depth) and water velocity. A staff gauge (graduated into feet and tenths of feet (meters and centimeters) can be used to directly measure depths of shallow streams and rivers at select points perpendicular to the stream flow. If the bottom profile of the stream or river is undulating or complicated in some manner, the sum of the volumetric flows of the individual areas making up the cross-section can determine the overall volumetric flow rate. This will require calculating the individual areas and determination of corresponding velocities in those areas. For relatively simple geometries, a simple depth measurement and velocity determination can be directly made. For complicated geometries and deep water (greater than approximately 2.5 feet) multiple velocity readings,

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using one of a number of velocity specific and calibrated electronic or magnetic flow meters will be required.

An alternative method for directly reading stream or river volumetric flows, at locations that require repeated sampling, may be to install a permanent Weir or Flume that can be used to channel flow and read volumetric flows directly. If this method is utilized, it will require plans and specifications for the design and construction of the structure.

The proper collection of representative surface water samples will also be dependent on the geometry and depths of the surface water to be sampled and the contaminant of concern. Surface water can be sampled through direct filling of contaminant specific sample containers or through collection of the sample in a pre-defined sample collection device where the sample is then transferred to the sample container. Generally, sampling of surface water from ponds and lakes do not require volumetric flows but will require knowledge of the total depth of the pond or lake and a predetermined knowledge of the depths from which samples are to be collected.

The choice of the proper location to collect a surface water sample, the method to measure areas and velocities and the proper choice of the materials of construction and type of flow meter and sample collection device is site and contaminant-specific and shall be defined in the work plans.

All work performed determining areas, velocities and collection of representative samples should be thoroughly documented on a DFR using diagrams. Photographs and a photo log will also be used to document the methods used for measuring flow.

6.1.1 Choosing a Transect Location

Stream flow measurements are performed along a transect of the stream. The transect location should include an area of moving water that can be waded and in an area of channelized flow. Hip boots or Knee-high water tight boots will be used for wading in streams. The transect location should be chosen based on a variety of general criteria ranging from point-source outfalls of concern, stream morphology, accessibility, safety concerns, and the location of preestablished sample locations. Once chosen, a transect location should be documented to provide a basis for repetition and comparison with previous or future sample events.

Stream specific criteria for selecting a transect location include looking for particular characteristics such as:



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- a well defined and stable stream bank;
- few obstructions in the channel; and
- no eddies or still water.

Conversely, turbulent water should also be avoided, if possible. The stream should be free flowing and unrestricted by obstructions upstream or downstream, which might cause flow diversion or flow backup. A smooth streambed profile, one of relatively consistent depth across its width, is optimal. The depth of the stream must be adequate for the determination of a flow velocity and subsequent collection of the surface water sample without disturbing the stream bottom sediment.

For purposes of reproducibility, any likely movable objects within the stream bed, which may interfere with the reproducibility with subsequent sample collection events should be removed, if possible and allowable. Removal of channel obstructions, (i.e., woody debris, rocks, or other obstructions), should be performed to allowed sufficient time for stream flow re-stabilization before flow measurements are recorded.

6.1.2 **Setup**

Once a transect location is selected, the stream flow equipment should be laid out as close to the transect as safety allows.

- Lay out tarps near the area where readings are to be performed, one for equipment, and one for staff seating and miscellaneous supplies.
- Unload equipment and setup the workstation, allowing for easy access to needed materials.
- If contaminants are expected (such as pathogens), establish a decontamination area with another tarp where staff will be exiting the stream. Place decontamination supplies (sprayer bottles with bleach solution and distilled rinse water) in this area.
- If the banks of the stream are steep, place a ladder against the bank for safe ingress and egress.

6.1.3 Setting up the Transect

If the stream to be sampled is more than a few (five) feet across and the bottom profile of the stream is geometrically complicated, a transect for defining the area of the stream (by defined



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small sub-areas of depth) will be defined and measured in the field. The following procedures describe the process for setting up the transect.

- Setup the transect endpoints by driving a stake into the ground on each side of the stream. The resulting transect should be at right angles to the stream flow.
- Stretch a line (polyester pre-stretched line) across the stream and fasten to each stake, ensuring the line remains taut and as near the surface of the water as possible.
- Facing upstream, align the zero increment of the tape measure with the left edge of
 water and mark the line or secure the measuring tape to the line across the width of
 the stream using zip ties. If available, fasten the side of the tape measure marked in
 tenth of foot increments face-up. It may be convenient to fasten the tape measure to
 the line at the specific locations where measurements will be taken.
- Measure the total width of the stream.
- Determine the spacing of the stream velocity readings to be collected based on the width of the stream. The reading locations should be tenths of feet; equal distances apart, with 20 to 30 readings for streams wider than 20 feet, at one-foot intervals for streams between 5 and 20 feet wide, and 0.2 feet for streams less than 5 feet wide. For example, if a stream is 46 feet wide, a spacing of 2 feet (24 readings including both edges) would be preferred to a spacing of 1½ feet (30 readings). The first and last reading locations for each transect should fall at or outside the left and right edges of the water and will have zero velocity and zero depth.

If a boat or raft will be used to take the readings because the stream cannot be safely waded, the boat or raft must be stabilized against movement at each transect station but allowed to be moved across the stream as measurements dictate. A line (preferably polyester pre-stretch) tied to existing secure objects such as trees, guardrails, or other stationary objects (one on either side of the stream) should be attached to the boat through cleats, cams or eyelets on the boat or raft (and secured by appropriate knots (such as a bowline)) to enable the line to be untied. The objects should be as far upstream of the transect as the width of the stream. The lines must be independently adjustable on the boat to allow for freedom of movement along the transect yet allowing stability from downstream or lateral drift. If stationary objects are not available, vehicles, securely driven stakes, or two secure anchors on each stream bank may be necessary. Motors, if used, should not be used during actual velocity readings or sample collection.



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6.1.4 Measurement of Stream Depth

The depth of the stream should be measured at each point of the transect using equipment specific to the approximate depth encountered. For depths less than 5-feet, a staff gauge or steel measuring tape, in a vertical position, can be used to measure depth directly in feet and tenths of feet. If the velocity of the stream is too great, the turbulence around the gauge may make accurate and reproducible readings difficult. In this case, a PVC pipe, longer than the stream is deep and perforated near the bottom to allow communication with the stream flow, can be used to minimize the turbulence around the staff gauge while measuring the depth. The tube should be placed in the location of the measurement, the water level in the tube allowed to come to equilibrium and then the staff gauge used through the tube. Care should be taken to not disturb the sediment or organisms on the bottom of the stream bed.

For greater depths, a graduated measuring, and weighted, line may be used or an electronic depth meter for situations such as lakes and deep ponds.

Document the location of the measurement by using a GPS device.

6.1.5 Measurement of Stream Velocity

There are a number of velocity measuring methods/devices that can be used for determination of the stream velocity at each sampling location or at each point of a transect. The methods for velocity determination will be defined in the work plan with the prior knowledge of each sample collection point location. The procedures for the proper calibration and use of velocity meters are well defined by the US Geological Survey and other State and Federal agencies as well as manufacturers of the meters. The measurements should follow these procedures and be made by staff with experience with the meters to be used.

For streams with simple geometry and steady laminar flow, the flow may not deep enough to fully submerge any of the available flow velocity meters. In this instance a simple method for velocity determination is to measure the rate of travel of a float on the surface of the water using a defined distance along the axis of the stream an accurate stop watch. If this method is used, at least 10 repetitions of the measurement should be made and an average of the 10 velocities used in the subsequent volumetric flow determination. Regardless of stream width, a minimum of two passes of velocity measurements should be taken; once traveling left to right facing upstream, once traveling right to left facing upstream.



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For most stream flow situations that may be encountered, where the stream can be safely waded, a velocity reading should be collected at each transect location using a calibrated velocity meter such as a Pygmy meter, Price AA meter, Acoustic Doppler Meter or Marsh-McBirney electronic direct reading meter. For each of these, a vertical profile of the stream velocity, at each transect whole foot location (see above) shall be measured as follows:

- Depths ≤ 2.5 Feet: One measurement should be taken at 60% of the depth at each measurement location.
- Depths >2.5 Feet: Two measurements should be taken: at 20% and 80% of the total depth at each measurement location.

The use of these in-stream measuring devices usually includes the use of a Wading Rod, which is a tool that is designed and constructed to easily set and hold the flow meter at the desired location and the desired depth (20%, 60% or 80%) using a defined set of gradations on the Rod and instructions that accompany the meters.

6.1.6 Measurement of Flow Velocities

For all velocity readings, the Wading Rod should be kept vertical and the meter perpendicular to the flow. For those streams with multiple measurements across a transect, measure and record the velocity, move to the next location along the transect, and repeat the procedure until reaching the opposite bank. At least one measurement should be made at each pre-determined measurement point along the transect, however additional measurements along the transect can be used to help average the flow if the site conditions suggest that this is appropriate.

6.1.7 Calculating Stream Flow

Once the velocity and depth of the points along the transect have been determined, the midsection method can be used for determining the stream flow. Compute the volumetric flow in each transect increment by multiplying the averaged velocity, or single velocity in streams less than 2.5 feet deep, in each increment by the area determined for that transect increment (depth times width). Note that the first and last increments are located at the edge of the stream and have a depth and velocity of zero. Sum the volumetric flow for each increment to compute total stream flow. Record all measurements and the resulting flow in cubic feet (or cubic meters) per second on the appropriate field forms.



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6.2 SURFACE WATER SAMPLING

Preparation and execution of surface water sampling will be performed by appropriately trained field staff under the guidance of a California-licensed Professional Geologist, Hydrologist, or Professional Engineer. Surface water sampling preparation and surface water sampling techniques will be defined in the work plan and general requirements are discussed below.

6.2.1 Preparation

Prior to performing the sampling, the following tasks will be completed:

- Determine the extent of the sampling effort, the sampling methods to be employed, and which specific equipment and supplies are needed (these will be defined by the stream, lake or pond characteristics and the contaminants of concern).
- Obtain necessary sampling and monitoring equipment.
- Decontaminate all sampling equipment and ensure that it is in working order.
- Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
- Scout proposed locations to ensure accessibility and sampling feasibility.
- Use stakes, flags, or buoys to identify and mark all planned sampling locations. If required, the proposed locations may be adjusted based on site access, property, boundaries, and obstructions.

Things to consider before sampling include:

- Will the sample be collected from the shore or from a boat on the impoundment?
- What is the desired depth at which the sample is to be collected?
- What is the overall depth and flow direction of a river or stream?
- What is the chemical nature of the analyte(s) of concern? Do they float on the water surface (collect by skimming the surface) or are the miscible (soluble) and are more likely to be present at depths (collect sub-surface)?

These considerations will help to dictate the sample equipment to be used during the sample collection.



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6.2.2 **Surface Water Sampling Techniques**

Sampling of both aqueous and non-aqueous liquids is generally accomplished through the use of one of the following samplers or techniques:

- Dip Sampler;
- Direct Method;
- Discrete Depth Samplers;
- Peristaltic Pumps.

Sampling situations vary widely and other techniques may be available, however these sampling techniques will allow for collection of representative samples from the majority of streams, rivers, lakes and ponds.

Sample collection devices must be of a proper composition based upon the analyses to be performed. For example, devices which are free of metal surfaces should be used for collecting samples for metal analyses. The SAP and work plan will define the materials of construction that can come into contact with the water to be sampled as well as the laboratory prepared sample containers and preservatives (if any) to be used for the water samples.

6.2.2.1 Dip Sampler

A dip sampler is useful for situations where a sample is to be recovered from an outfall pipe or along a stream, lake or pond where direct access is limited. Generally a Dip sampler is a sample collection container (either open of capable of closing upon sample collection) mounted on a long pole that may be telescoping. The long handle on such a device allows access from a discrete location. Sampling procedures are as follows:

- 1. Assemble the device in accordance with the manufacturer's instructions.
- 2. Extend the device to the sample location and collect the sample.
- 3. Retrieve the sampler and transfer the sample to the appropriate sample container.

6.2.2.2 Direct Method

For streams, rivers, lakes, and other surface waters, the direct method may be utilized to collect water samples from the water surface. This method is typically not used for sampling lagoons, impoundments, or ponds where significant concentrations of contaminants are present.

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Use adequate protective clothing and gain access to the sampling station by appropriate means. For shallow stream stations, the sampler should face upstream and collect the sample upstream from where the sample personnel are standing and without disturbing sediment. Surface water samples should always be collected prior to a sediment sample at the same location. Submerge the closed sample container, open the bottle to collect the sample, and then cap the bottle while it remains under water.

When using the direct method, do not use pre-preserved sample bottles as the collection method may dilute the concentration of preservative necessary for proper sample preservation.

6.2.2.3 Discrete Depth Samplers

When samples are to be collected from discrete depths of a stream, river, lake or pond, the predetermined depths and contaminants of concern will define what specific sample collection devices should be used. There are sample collection devices that can be used to collect samples from shallow water (less than 2.5 feet) which are generally horizontal tubes (Kemmerer sampler) or deeper depths which generally use the same principal of sample collection (Van Dorn Sampler). Both samplers are lowered to the desired sampling depth and allowed to come to equilibrium with the flowing or steady water. The line which holds the sample device is connected to a spring loaded mechanism which allows the ends of the sample tube to close. The sampler is closed by sending a "messenger", typically a metal weight, down the line to the sampler where then the weight trips the spring and the sampler is closed. The following criteria should be followed:

- Using a properly decontaminated sampler, set the sampling device so that the sampling end pieces are pulled away from the sampling tube, allowing water to pass through the tube.
- Lower the pre-set sampling device to the predetermined depth. This requires
 knowledge of the total depth at the sample location. Avoid bottom/sediment
 disturbance. The line holding the sampler may need to be pre-marked to ensure
 that the proper depth is being sampled.
- 3. When the discrete sampler bottle is at the required depth, send down the messenger to close the sampling device.
- 4. Retrieve the sampler and discharge the first 10 to 20 milliliter (mL) to clear any potential contamination of the valve. Transfer the water sample to the appropriate sample container in accordance with SOP 1.0 Field Documentation and Sample Handling and SOP 3.0 Field Measurements Water.

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- 5. Be sure to use special attachments available on some discrete samplers to distribute small volumes at low flow rates, when appropriate.
- 6. Document the surface location of the surface water sample using a GPS device.

6.2.2.4 Peristaltic Pump Samplers

A peristaltic pump can be used to collect a sample from the water column at most depths of interest in a stream or river. Tubing (the composition of which will be defined in the work plan) is lowered to the desired sample depth (using weights to ensure that the tubing is placed to the correct depth) and connected at the surface to the peristaltic pump.

Typically peristaltic pumps work to a depth of approximately 25 feet below ground surface. Because of the overlying water, deeper depths can be sampled but may not be efficient due to the low pumping rates of peristaltic pumps and the sample volume that may be needed for sample analysis. Commercially available pumps vary in size and capability, with some being designed specifically for the simultaneous collection of multiple water samples. Due to the various pumps available no universal sampling procedure is available and the sampler should follow the procedures provided in the instruction manual for the pump.



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6.3 REVISION LOG

Revision Number	Author	Description of Change (Section number)	

ATTACHMENTS

Stream Flow (Discharge) Measurement Form



Stream Flow (Discharge) Measurement Form

Site Description				GPS ID			
Stream				Date/Time	<u> </u>		
Samplers Present	t			Weather	' -		
Stream width (10' upstream)				Stream depth (10' upstream)			
Stream width (10'	downstream)			Stream de	pth (10' downstream)		
Other Notes:							
Bucket method:	Bucket volume	(gal):					
Fill Times (sec):	1)	2)	3)	4)	5)		
	6)	7)	8)	9)	10)		
Calculated discha	irge:	gpm					
divide gpm by 448	3.8:	cfs					
Flume method: Flume type:		Estimated losses around flume (%):					
	Flume choke w	vidth:					
Measurements:		1)	2)	Other Flun	ne Installation Notes:		
Upstream Stage (0.1ft):							
Downstream Stage (0.1ft):							
Lookup discharge (cfs):							
Final Discharge ir	ncluding						
Estimated Losses	s (cfs):						
Flow Meter meth	od.	Flow Meter	Tyne:				

Flow Meter method: Flow Meter Type:

Pass 1 Calculated Discharge (cfs): Pass 2 Calculated Discharge (cfs):

Average Discharge (cfs):

	Pass 1		Pass 2			
Flow computer d			Flow computer datafile:			
Direction facing upstream; circle (R to L) (L to R)			Direction facing upstream; circle (R to L) (L to R)			
Tape (0.1 ft)	Depth (0.1 ft)	Velocity (ft/s)	Tape (0.1 ft)	Depth (0.1 ft)	Velocity (ft/s)	
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